CORNELL UNIVERSITY
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Announcement of The College of Engineering

Comprising

The School of Civil Engineering
The Sibley School of Mechanical Engineering
The School of Electrical Engineering

and

Announcement of
The Engineering Division of
The Graduate School

for 1935-36

Ithaca, New York
Published by the University
February 1, 1935

THE UNIVERSITY CALENDAR FOR 1935–36

1935			FIRST TERM	
Sept.	16,	*Monday,*	Entrance examinations begin.	
Sept.	23,	*Monday,*	Registration and assignment of new students.	
Sept.	24,	*Tuesday,*		
Sept.	24,	*Tuesday,*	Registration and assignment of old students.	
Sept.	25,	*Wednesday,*		
Sept.	26,	*Thursday,*	Instruction begins at 8 A. M.	
Oct.	18,	*Friday,*	Last day for payment of tuition for the first term.	
Nov.	27,	*Wednesday,*	Instruction ends at 6 P. M.	Thanksgiving Recess
Dec.	2,	*Monday,*	Instruction resumed at 8 A. M.	
Dec.	21,	*Saturday*	Instruction ends at 1 P. M.	Christmas Recess
1936				
Jan.	6,	*Monday,*	Instruction resumed, 8 A. M.	
Jan.	11,	*Saturday,*	Founder's Day	
Jan.	25,	*Saturday,*	Instruction ends.	
Jan.	27,	*Monday,*	Term examinations begin.	
Feb.	5,	*Wednesday,*	Term ends.	
Feb.	6,	*Thursday,*	A holiday.	
			SECOND TERM	
Feb.	7,	*Friday,*	Registration of all students.	
Feb.	10,	*Monday,*	Instruction begins at 8 A. M.	
March	2,	*Monday*	Last day for payment of tuition for the second term.	
March	28,	*Saturday,*	Instruction ends at 1 P. M.	Spring Recess
April	6,	*Monday,*	Instruction resumed, 8 A. M.	
May	—,	*Saturday,*	Spring Day: a holiday.	
June	1,	*Monday,*	Term examinations begin.	
June	9,	*Tuesday,*	End of term examinations.	
June	15,	*Monday,*	COMMENCEMENT.	

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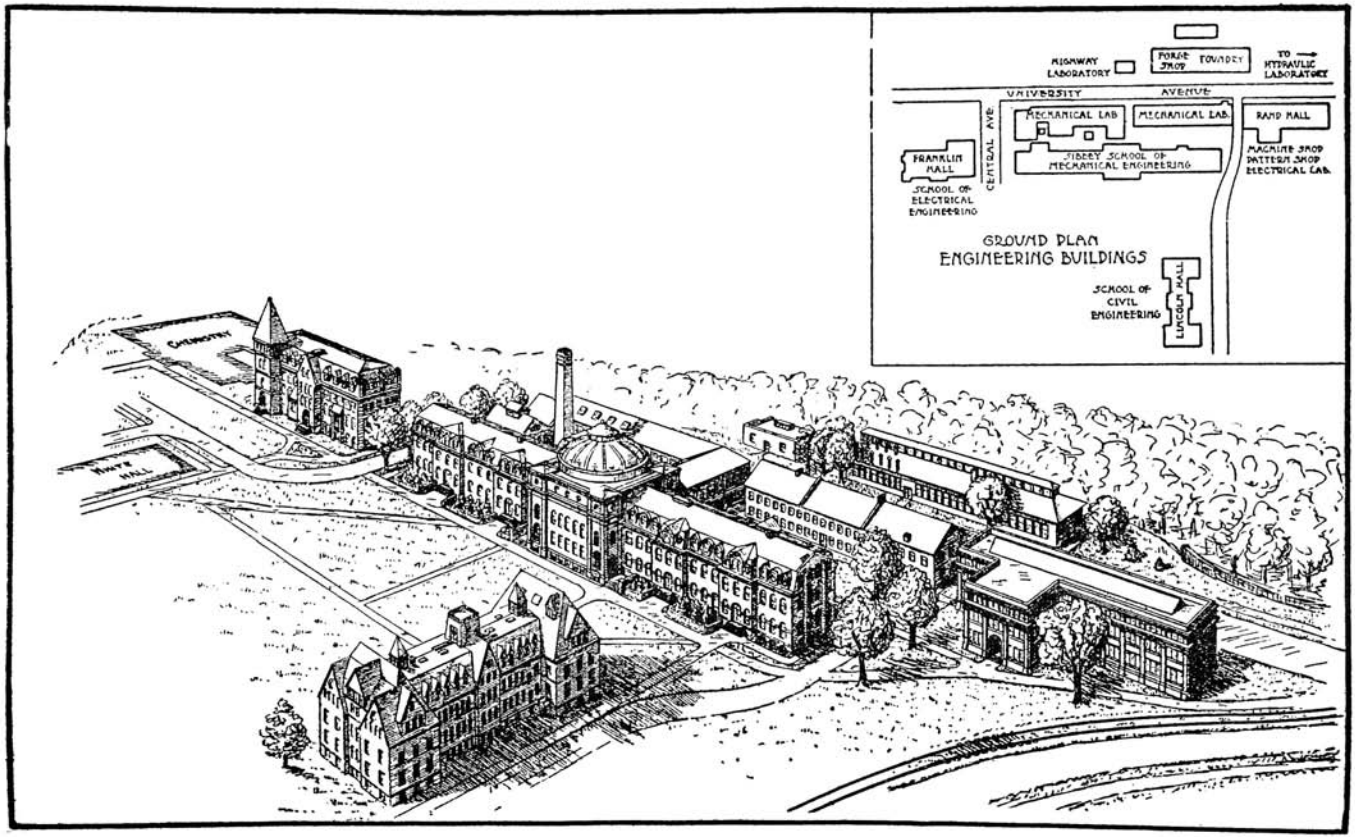

HIGHWAY LABORATORY
FORGE SHOP
FOUNDRY
TO HYDRAULIC LABORATORY
UNIVERSITY AVENUE
CENTRAL AVE
MECHANICAL LAB
MECHANICAL LAB
RAND HALL
FRANKLIN HALL
SIBLEY SCHOOL OF MECHANICAL ENGINEERING
MACHINE SHOP
PATTERN SHOP
ELECTRICAL LAB
SCHOOL OF ELECTRICAL ENGINEERING
GROUND PLAN
ENGINEERING BUILDINGS
SCHOOL OF CIVIL ENGINEERING
LINCOLN HALL
CHEMISTRY
WHITE HALL

A HISTORY OF THE COLLEGE OF ENGINEERING

CORNELL UNIVERSITY had its beginning in the Federal Government's grant, for the endowment of education in the several States, of a large portion of the public lands, under the authority of the Morrill Act, an Act of Congress approved by President Lincoln in 1862. The purpose of the Morrill Act was to endow in each State at least one college; by an express provision of the Act, a leading object of each of those colleges was to be the teaching of "such branches of learning as are related to . . . the mechanic arts." The State of New York devoted all the proceeds of its share of the land grant to Cornell University, which was established by charter in 1865 and was opened at Ithaca in 1868. In the very first plan of this University, therefore, was the foundation of a College of Engineering.

EZRA CORNELL, who had brought an eminent talent for practical affairs to the organizing and upbuilding of the telegraph business before and after the creation of the Western Union Telegraph Company, and who had retired in 1858, gave generously of his wealth and lavishly of his powers to the University's establishment. His wise management of New York's share of the land grant multiplied the endowment.

When Cornell University began its work, in 1868, it included a College of Mathematics and Engineering and a College of Mechanic Arts. The former of these consisted of two schools, namely, a school of mathematics and a school of civil engineering. In 1871 mathematics was set apart, and architecture was associated with civil engineering in a single college until 1873, when another separation took place, and civil engineering was organized as a department; it retained that form until 1890, when the College of Civil Engineering was established.

HIRAM SIBLEY OF ROCHESTER, the founder and first president of the Western Union Telegraph Company, a trustee of the University from 1865 until his death in 1888, was a liberal benefactor of the University's department of mechanical engineering. In 1871 he erected a building to house what was then called the College of Mechanic Arts, equipped it, and endowed the Sibley Professorship of Mechanic Arts to the amount of fifty thousand dollars. During the years from 1870 to 1887, Mr. Sibley gave more than $180,000 for the building and equipment of lecture halls, shops, and laboratories. His benefactions have been continued by his son, Mr. Hiram W. Sibley, who has given about $170,000 for construction and equipment.

The original College of Mechanic Arts offered instruction in shop work, drawing, and elementary engineering, in conformity with the provisions of the Morrill Act and the Charter, and provided a theoretical and practical course of four years leading to the bachelor's degree in mechanical engineering. In 1885, in recognition of the growth in importance of the profession of mechanical engineering,

the college was renamed The Sibley College of Mechanical Engineering and the Mechanic Arts.

Courses in electrical engineering were first established at Cornell in 1883, under the guidance of the Department of Physics. In 1889 the direction of the professional courses in electrical engineering was transferred to Sibley College and the present course in electrical engineering was developed within that college.

In 1919 the Board of Trustees, recognizing that all practice in engineering has a common groundwork, voted to consolidate all instruction in engineering at Cornell in a single institution to be called The College of Engineering. This single college comprises three schools, namely, the School of Civil Engineering, the Sibley School of Mechanical Engineering, and the School of Electrical Engineering. The last-named school has grown from the former department of electrical engineering in Sibley College. The combination has proved itself to be sound educationally, to be in harmony with the progress of industry, and to have administrative merit.

Besides the College of Engineering, Cornell University comprises the Graduate School, in which the student's work may lead to the degree of Doctor of Philosophy, to the degree of Doctor of the Science of Law, or to the master's degree in arts, science, agriculture, architecture, fine arts, landscape architecture, forestry, chemistry, laws, education, civil engineering, mechanical engineering, or electrical engineering; the College of Arts and Sciences, whose courses lead to the degree of Bachelor of Arts or that of Bachelor of Chemistry; the Law School; the Medical College, which gives most of its instruction in its main building at 1300 York Avenue, New York City; the New York State Veterinary College; the New York State College of Agriculture; the New York State College of Home Economics; and the College of Architecture, in which a student may earn the degree of Bachelor of Architecture, Bachelor of Landscape Architecture, or Bachelor of Fine Arts. There are about nine hundred persons in the University's teaching staff and its students number about five thousand.

The College of Engineering has intimate relations with the rest of the University. Its students, constituting about one-fourth of the University's whole enrollment, are associated with the faculties and students of the other colleges. This is an association in which the student extends his intellectual horizon and gains a clearer understanding of the relation of engineering to other human interests.

The University is situated at Ithaca, in the central part of the State of New York, about seven hours by rail from the City of New York and about three hours from Buffalo. Ithaca is accessible by way of two trunk lines, the Lackawanna and Lehigh Valley Railroads, and it has connections by rail with several stations on the New York Central system. The University's campus and contiguous lands occupy about fifteen hundred acres. The campus is on a hill, overlooking the city of Ithaca and a good many miles of Cayuga Lake.

THE FACULTY

THE COLLEGE OF ENGINEERING

LIVINGSTON FARRAND, A.B., M.D., L.H.D., LL.D., President of the University.
ALBERT RUSSELL MANN, A.M., D.Sc., D.Agr., LL.D., Provost of the University.
DEXTER SIMPSON KIMBALL, A.B., M.E., D.Sc., D.Eng., LL.D., Dean of the College and Professor of Mechanical Engineering.
MAUDE S. NEWMAN, Secretary of the College.

THE SCHOOL OF CIVIL ENGINEERING

SOLOMON CADY HOLLISTER, B.S., C.E., Director of the School, and Professor of Civil Engineering.
HENRY SYLVESTER JACOBY, C.E., Professor of Bridge Engineering, Emeritus.
HENRY NEELY OGDEN, C.E., Professor of Sanitary Engineering.
FRED ASA BARNES, M.C.E., Professor of Railroad Engineering.
SIDNEY GONZALES GEORGE, C.E., Professor of Mechanics of Engineering.
JOHN THOMAS PARSON, Professor of Drawing.
ERNEST WILLIAM SCHODER, Ph.D., World War Memorial Professor of Experimental Hydraulics.
FRANCIS JOSEPH SEERY, S.B., Professor of Hydraulic Engineering.
SAMUEL LATIMER BOOTHROYD, M.S., Professor of Astronomy.
ERNEST WILLIAM RETTGER, Ph.D., Professor of Mechanics of Engineering.
CHARLES LEOPOLD WALKER, C.E., Professor of Sanitary Engineering and Secretary of the College Faculty.
PAUL HALLADAY UNDERWOOD, C.E., Professor of Surveying.
HERBERT HENRY SCOFIELD, M.E., Professor of Testing Materials.
WALTER L. CONWELL, C.E., Professor of Highway Engineering.
LEONARD CHURCH URQUHART, C.E., Professor of Structural Engineering.
GILMORE DAVID CLARKE, B.S., Professor of Regional Planning.
MILES ALBION POND, Ph.B., Assistant Professor of Descriptive Geometry.
EARLE NELSON BURROWS, M.C.E., Assistant Professor of Structural Engineering.
LEONARD ALEXANDER LAWRENCE, B.S., Assistant Professor of Surveying.
CARL CRANDALL, C.E., Assistant Professor of Railroad Engineering, and Secretary of the Faculty of Civil Engineering.
JOHN EDWIN PERRY, B.S. in C.E., Assistant Professor of Railroad Engineering, and Personnel Officer of the School of Civil Engineering.
CHARLES EDWARD O'ROURKE, C.E., Assistant Professor of Structural Engineering.
ERIC VAIL HOWELL, M.C.E., Assistant Professor of Mechanics.
ROMEYN Y. THATCHER, C.E., Assistant Professor of Railroad Engineering.
CLAUDE M. PENDLETON, C.E., Marc Eidlitz Instructor in Civil Engineering.
ARTHUR F. BOYLES, C.E., Instructor in Surveying.
FRED J. SPRY, M.C.E., Instructor in Surveying.
LOWELL J. CHAWNER, A.B., C.E., McMullen Research Scholar and Instructor in Structural Engineering.
ARTHUR N. VANDERLIP, M.C.E., McMullen Research Scholar and Instructor in Testing Materials.

The Sibley School of Mechanical Engineering

Herman Diederichs, M.E., Director of the School, John E. Sweet Professor in Engineering, and Professor of Experimental Engineering.

Albert William Smith, B.M.E., M.M.E., Professor of Mechanical Engineering, Emeritus.

George Robert McDermott, Professor of Structural Design, Emeritus.

Millard Clayton Ernsberger, A.B., M.E., Professor of Power Engineering, Emeritus.

William Nichols Barnard, M.E., Professor of Heat-Power Engineering.

Edgar Harper Wood, M.M.E., Professor of Mechanics of Engineering.

Calvin Dodge Albert, M.E., Professor of Machine Design.

Albert Edward Wells, Sibley Professor of Mechanic Arts.

Frank Oakes Ellenwood, A.B., M.E., Professor of Heat-Power Engineering.

Will Miller Sawdon, B.S., M.M.E., Professor of Experimental Engineering, assigned to Engineering Research.

George Burr Upton, M.M.E., Professor of Experimental Engineering.

Seymour Stanton Garrett, C.E., World War Memorial Professor of Industrial Economics.

Victor Raymond Gage, M.M.E., Professor of Experimental Engineering.

Myron A. Lee, M.M.E., Professor of Industrial Engineering.

Frederick George Switzer, M.M.E., Professor of Hydraulic Engineering.

Clarence Ellsworth Townsend, M.E., Professor of Engineering Drawing.

Fred Stillman Rogers, B.S., M.E., Professor of Machine Design.

Adam Clarke Davis, jr., M.E., Professor of Experimental Engineering.

Walter Rodney Cornell, B.S., C.E., Professor of Mechanics of Engineering.

John Robert Bangs, jr., M.E., Professor of Administrative Engineering and Personnel Director of the College of Engineering.

Roy Edwards Clark, M.E., Assistant Professor of Heat-Power Engineering.

Enoch Francis Garner, M.E., Assistant Professor of Machine Design.

Warren Howard Hook, M.E., Assistant Professor of Heat-Power Engineering.

William Emerson Mordoff, M.E., Assistant Professor of Machine Construction.

Harold Charles Perkins, M.E., Assistant Professor of Mechanics of Engineering.

William Cook Andrae, M.M.E., Assistant Professor of Experimental Engineering.

Karl Dawson Wood, M.E., M.S., Assistant Professor of Mechanics of Engineering.

Charles Osborn Mackey, M.E., Assistant Professor of Heat-Power Engineering.

Dexter Simpson Kimball, jr., M.M.E., Assistant Professor of Industrial Engineering.

Stephan Farrell Cleary, M.M.E., Instructor in Engineering Drawing.

Leslie A. Fenner, M.E., Instructor in Engineering Drawing.

George Raymond Hanselman, M.E., Instructor in Administrative Engineering.

Robert Cunningham Morris, Instructor in Machine Design.

Carroll Bromley Clark, M.E., Instructor in Experimental Engineering.

Joseph Olmstead Jeffrey, M.E., Instructor in Experimental Engineering.

Clyde Ira Millard, E.E., Instructor in Administrative Engineering.
Harrison Louis Goodman, M.E., Instructor in Experimental Engineering.
Ludolph Frisch Welanetz, M.E., McMullen Research Scholar and Instructor in Experimental Engineering.
John Robert Moynihan, M.E., McMullen Research Scholar and Instructor in Experimental Engineering.
Floyd Cleveland Knight, M.E., Instructor in Machine Design.
Cyril Waldie Terry, M.E., Instructor in Machine Design.
Roland Lloyd Roy, B.S. in E.E., M.S., Instructor in Industrial Engineering.
Ralph W. Hodges, Instructor in Introductory Engineering Laboratory.
Harry J. Loberg, M.E., Instructor in Administrative Engineering.
Kennedy Furlong Rubert, jr., M.M.E., Aero.E., Instructor in Experimental Engineering.
Henry Davis Daboll, Assistant Instructor in Industrial Engineering.

SHOP ASSISTANTS

Burdette N. Howe, Foreman in the Machine Shop.
Charles E. Patterson, Foreman in the Foundry.
Walter Liston Head, Assistant in Introductory Engineering Laboratory.
Howard Stanley Bush, Assistant in the Pattern Shop.
Ernest Stanley Yawger, Assistant in the Pattern Shop.
Rudolph P. Schallowitz, Assistant in the Machine Shop.

The School of Electrical Engineering

Paul Martyn Lincoln, M.E. (in E.E.), LL.D., Director of the School and Professor of Electrical Engineering.
Vladimir Karapetoff, C.E., M.M.E., Professor of Electrical Engineering.
William Cyrus Ballard, jr., M.E. (in E.E.), Professor of Electrical Engineering.
Robert Franklin Chamberlain, M.E. (in E.E.), Professor of Electrical Engineering.
Burdette Kibbe Northrop, M.E. (in E.E.), Assistant Professor of Electrical Engineering.
Lawrence Adams Burckmyer, jr., B.S. (in E.E.), E.E., Assistant Professor of Electrical Engineering.
Everett Milton Strong, B.S. in E.E., Assistant Professor of Electrical Engineering.
True McLean, E.E., Assistant Professor of Electrical Engineering.
Michel George Malti, B.A., B.S. in E.E., M.E.E., Ph.D., Assistant Professor of Electrical Engineering.
Miles Gordon Northrop, E.E., Assistant Professor of Electrical Engineering.
Walter Wendell Cotner, M.E.E., Instructor in Electrical Engineering.
Wilber Ernest Meserve, M.S., M.E.E., Ph.D., Instructor in Electrical Engineering.
Dimiter Ramadanoff, B.S. in E.E., Ph.D., McMullen Research Scholar and Instructor in Electrical Engineering.
Edmund Robert Paige, B.E., M.E.E., Instructor in Electrical Engineering.

Frank Jessup Bristol, E.E., Instructor in Electrical Engineering.
William Daniel Moeder, E.E., Instructor in Electrical Engineering.
Arne Wikstrom, E.E., Instructor in Electrical Engineering.
John Palen Wood, M.E., M.E.E., Instructor in Electrical Engineering.
Harry Sohon, M.E.E., Ph.D., McMullen Research Scholar and Instructor in Electrical Engineering.

OTHER OFFICERS

Dorothy Savercool, Recorder.
Lulu M. Markell, Secretary to the Dean.
Mary R. Korherr, Secretary to the Director of the School of Civil Engineering.
Mabel H. Walbridge, Librarian of the School of Civil Engineering.
Clinton D. Cass, Mechanician of the School of Civil Engineering.
Lena Gertrude Marsh, Librarian of the Sibley School of Mechanical Engineering.
J. Grace Simpson, Secretary to the Director of the Sibley School of Mechanical Engineering.
Margaret Komaromi, Clerk of Personnel and Employment Department.
George Washington Race, Mechanician in the Sibley School of Mechanical Engineering.
Samuel Cornelius Patch, Mechanician in the Sibley School of Mechanical Engineering.
Alfred William Neigh, Engineer in the Sibley School of Mechanical Engineering.
Virgil Neigh, Assistant Mechanician in the Sibley School of Mechanical Engineering.
Katherine Handlen, Secretary to the Director of the School of Electrical Engineering.
Mrs. I. M. Batchelor, Librarian of the School of Electrical Engineering.
George Alfred Culligan, Mechanician in the School of Electrical Engineering.

INSTRUCTION OFFERED IN ENGINEERING

Cornell University offers both undergraduate and graduate instruction in engineering, the former in the College of Engineering and the latter in the Engineering Division of the Graduate School of the University. The first part of this Announcement relates primarily to the undergraduate instruction. For information regarding graduate work in engineering, see page 115.

Purpose of the Instruction

Thorough Training in Fundamentals

The curricula of the Schools of the College of Engineering consist, primarily, of courses designed to teach the fundamental principles, theoretical and practical that underlie the various branches of engineering. In addition, such work is required in pure and applied economics as is needed by the engineer of the present time. Late in the course some degree of specialization is permitted; but since the time allowed for this is quite limited, specialization cannot be carried very far. In fact, the Faculty of Engineering is strongly of the opinion that the duty of the technical school to its undergraduates is to train them thoroughly in the fundamental subjects and that the four-year course is not too long for this purpose. Hence the demand for the introduction of specialization early in the course has always been resisted.

It is well recognized that theoretical instruction must be supplemented by experience in practice and by contact with life before one can attain his greatest usefulness in the profession; hence an effort is made to bring the student into contact with teachers who are closely in touch with engineering practice, to the end that he may thus become familiar with problems encountered in modern engineering and with practical methods of solving them. It is hoped in this way to shorten somewhat the period of adjustment for the graduate when he begins actual engineering work.

Five and Six-Year Courses Recommended

Since the work in the regular four-year course in this College is largely technical, it is desirable that the student devote more time to his course in order to broaden the training. This may be done by devoting five or six years.

In a five-year course, the student enters the College of Engineering with the regular entrance, and pursues the regular work for two or three years. After having obtained the fundamentals in engineering in this way, he may then spread the rest of the engineering work of the regular four-year course over three or two years more and add, in the way of electives, the equivalent of one year's work in the field of liberal arts.

A SIX-YEAR COURSE leading to the degrees of A.B. and C.E., or A.B. and M.E., or A.B. and E.E. is recommended for students who can afford the additional time and expense. The entrance requirements for this course include less mathematical preparation than is specified for the four-year or five-year course, but the student must meet the entrance requirements specified by the College of Arts and Sciences, in which he will be enrolled for the first four years. The necessary arrangement of his studies in the course is set forth under the head of Admission to the Six-year Course, on page 41.

Owing to the large amount of liberal work in the curriculum, the two degrees of A.B. and C.E. may be obtained in five years plus two summer sessions.

In conjunction with the Department of Chemistry of the College of Arts and Sciences, the College of Engineering offers a five-year course in Chemical Engineering. Students in this course register, for the first four years, in the College of Arts and Sciences with the entrance requirements specified for the degree of B.Chem. This degree is conferred at the end of four years. For the fifth year, registration is in the College of Engineering, Sibley School of Mechanical Engineering. The Degree of Chemical Engineer is conferred at the end of the fifth year. For details of this course see page 89.

The Schools of Civil, Mechanical, and Electrical Engineering also offer four-year courses in Administrative Engineering, leading to the degree of B.S. in Administrative Engineering. For details of these courses see pages 58, 90, and 108.

In addition to the prescribed courses in the College of Engineering, those students who have the necessary time available may elect, with the permission of their class adviser, any course in any college of the University, provided they have had the required preparation for the work.

The General Plan of Studies

As already stated, the course of preparatory and professional studies has been planned with a view to laying a substantial foundation for the general and technical knowledge needed by practitioners in civil, mechanical, and electrical engineering, so that the graduates, guided by their theoretical education, and as much of engineering practice as can well be taught in schools, may develop into useful investigators and constructors.

The facilities for instruction, both fundamental and advanced, are extensive. The students entering upon the work of the first term in the College take practically the same courses, it being recognized that the fundamental work should be the same for all engineers.

For the Courses of Instruction, covering the work of the first year for all engineering students, see pages 48–50 of this Announcement. The work of the last three years is outlined on pages 56–59 for civil

engineers, on pages 83–92 for mechanical engineers, and on pages 106–109 for electrical engineers.

In general the work of the freshman students comprises fundamental training in mathematics, physics, chemistry, drawing, surveying, and shop work.

CIVIL ENGINEERING students follow this with as thorough a preparation as possible for the general purpose of the profession in the following subjects: the survey, design, and construction of buildings, roads, railroads, canals, sewers, and water works; the construction of foundations under water and on land, and of super-structures and tunnels; the survey, improvement, and protection of coasts, and the regulation of rivers, harbors, and lakes; the astronomical determination of geographical coordinates for geodetic and other purposes; the application of mechanics, graphical statics, and descriptive geometry to the construction of the various kinds of arches, girders, roofs, trusses, suspension and cantilever bridges; the drainage of districts, sewerage of towns and irrigation and reclaiming of land; the application, and tests of hydraulic and electric motors and steam engines; the preparation of drawings, plans, specifications, and the proper inspection and tests of the materials used in construction. Instruction is given in engineering economy, finance, and jurisprudence. The latter subject deals in an elementary manner with the questions of easements and servitudes, and the fundamental principles of the law of contracts and riparian rights. Opportunity is also given to seniors to specialize to a limited extent, or to broaden their training, by the election of fifteen credit hours, nine of which may be chosen from approved courses in any department of the University.

MECHANICAL ENGINEERING students in the last three years of the course receive a thorough training in machine design, in shop methods and management, in thermodynamics and heat-power, in the fundamentals of electrical engineering, and in mechanical laboratory practice. They may in their last year specialize in heat-power work, steam or internal combustion engines, industrial engineering, water power, aeronautics, or in automotive engineering.

ELECTRICAL ENGINEERING students receive a thorough foundation in general engineering principles as well as in the principles and practice of Electrical Engineering. Students with proper qualifications may during the junior and senior years specialize in Physics. In the senior year students may elect to specialize in one of a number of different branches of Electrical Engineering such as

(a) Electrical Design

(b) Generation and Transmission of Electrical Energy

(c) Electrical Communication.

ADMINISTRATIVE ENGINEERING students, either in C.E., M.E. or E.E., receive first a fundamental grounding in Mathematics, Physics, Chemistry, Mechanics, and related basic subjects, which is, prin-

cipally in the last two years, supplemented by instruction in Economics, Accounting, Cost Finding, Corporation Finance, Marketing, Law, etc. The aim in this course is to preserve a strong engineering background.

CHEMICAL ENGINEERING students receive, during the first four years, a thorough training in inorganic and organic Chemistry supplemented by the fundamentals of Engineering. The fifth year is devoted largely to Industrial Chemistry and advanced engineering courses.

OPPORTUNITIES FOR EMPLOYMENT AFTER GRADUATION

A training in civil, mechanical, or electrical engineering opens wide opportunities for employment in all branches of industry.

CIVIL ENGINEERING graduates find employment in both technical and general business enterprises. In the technical field they are employed in the various branches of civil engineering; in surveying operations of all kinds, including land surveying, construction surveys, aerial surveys, and in the geological and geodetic surveys of the U. S. Government; in the design and construction of irrigation, reclamation, river and flood control, harbor improvement, and hydroelectric projects; in designing and constructing water supply systems, sewerage systems, filtration and purification plants; in the location, maintenance, construction, and operation of railroads; in all classes of highway work; in the design and construction of steel and reinforced concrete bridges and also of steel frame and reinforced concrete buildings; and in examining and testing the properties of materials. There is a growing field of service for the civil engineer in city and regional planning and in city management. Many civil engineers are also engaged in contracting. In the field of general business, experience clearly indicates increased opportunity in many business enterprises for the graduate in Civil Engineering because the training in analysis and precision are assets of value in the fields of finance valuations and real estate, and in other kindred activities of the business world.

MECHANICAL ENGINEERING underlies nearly all branches of the industries: its province includes the design, construction, operation and testing of steam engines, steam turbines, boilers and power-plant auxiliaries, gas and oil engines, with their auxiliaries, hydraulic machinery, pumping engines, railway equipment, compressed air machinery, ice-making and refrigerating machinery, equipment for heating and ventilation, machine tools, mill equipment and transmission machinery. The work of the mechanical engineer includes the planning of power plants and factories, the selection and installation of their equipment, the development of the systems of operation and of manufacturing processes, and the organization and administration of industries.

ELECTRICAL ENGINEERING includes the design, construction, operation, and testing of electrical equipment used for the generation, transmission, and utilization of electrical energy.

The graduate trained in ADMINISTRATIVE ENGINEERING is fitted to fill any one of the many positions in the borderland between engineering and business. From all available information, the demand for men in this field is growing.

Graduates of the course in CHEMICAL ENGINEERING find employment both as chemists and as managers of chemical industries.

From the foregoing very brief outline of some of the fields covered by the branches of engineering for which the students of the College of Engineering are fundamentally prepared, it is seen that the opportunities for graduates to obtain employment are broad. Graduates after gaining requisite experience in practice, usually occupy such positions as designers, supervisors of construction, inspectors, testers, research engineers, superintendents of departments, works managers, efficiency engineers, specialists in welfare work and in labor problems, consulting engineers, insurance investigators, commercial representatives, engineering salesmen, educators, and managers and presidents of commercial organizations.

Each school maintains an EMPLOYMENT BUREAU for its graduates. Correspondence should be addressed to the Director of the school concerned.

PERSONNEL SYSTEM

The College of Engineering operates a personnel system to aid the student in deciding the nature of the work for which he is best suited. It endeavors to point out his desirable as well as his undesirable characteristics with a view to correcting the latter if possible.

During the first and second years, the student is rated by his instructors. In the third and fourth years he is rated by a committee of five members of the faculty and five members of his own class whom he has selected as being especially capable of giving him an accurate rating. The complete rating is compiled by the personnel director and given to the student for his guidance. By this system there is available to every student information that he could not obtain otherwise and which should be of great value to him in laying part of the foundation for a successful career.

The personnel director acquaints himself with the desirable and undesirable traits of each student as indicated by the composite rating; points out to the student the advantages of carefully developing his desirable traits; decides which of the undesirable traits may be changed and advises the student accordingly. With such advice the student is in a position during the highly formative period of his life, to develop the characteristics which will aid him materially in later life.

VOCATIONAL COUNSEL. During the senior year each student is interviewed and an analysis of his aptitudes is made in order that he may intelligently interview representatives of business and industry.

A FIVE-YEAR SERVICE PLAN to graduates consists of circularizing the class at the beginning of each year for five years after graduation to learn of their work, success, and desires as to change in position.

Information regarding opportunities reaches the Dean's office, and graduates frequently are enabled to make very desirable connections through having up-to-date information regarding themselves on file with the personnel director.

BUILDINGS: LABORATORIES, LIBRARIES AND OTHER EQUIPMENT

BUILDINGS

The building occupied by the School of Civil Engineering is LINCOLN HALL, a substantial brownstone structure, 200 feet long and 70 feet wide. In addition to the laboratories and museums, the building contains the working library of the School, aggregating over five thousand volumes, reading rooms, classrooms, and drafting rooms. The astronomical equipment and portions of the geodetic equipment are housed in the Fuertes Observatory, which contains all the instruments required for determining time, latitude, longitude, and azimuth. Several of the instruments are duplicates of those used by the United States Coast and Geodetic Survey. A large hydraulic laboratory is situated at the lower end of Beebe Lake in Fall Creek Gorge, near Lincoln Hall.

The Sibley School of Mechanical Engineering received its name from the late Hiram Sibley of Rochester, who between the years 1870 and 1887, gave $180,000 toward its endowment and equipment. Mr. Hiram W. Sibley has added more than $170,000 for later constructions and equipment. The SIBLEY BUILDINGS are situated at the north end of the Campus, and stand upon ground leased from the University for the purposes of the School, under an agreement with the late Hiram Sibley. There are five large buildings in the group.

The main building is 370 feet long, 50 feet wide, and three stories in height. It contains the reading room and reference library, drawing rooms, lecture rooms, offices, classrooms, and a large and well-lighted auditorium.

The Department of Experimental Engineering occupies two two-story buildings, each about 150 feet long by 40 feet wide, besides a boiler plant 30 by 40 feet, a refrigeration laboratory 30 by 40 feet, and the east basement of the main building.

RAND HALL was added to the Sibley School group (at a cost of $60,000) through the generosity of Mrs. Florence O. R. Lang. This building is a memorial to Jasper R. Rand, Addison C. Rand, and Jasper R. Rand, jr., the father, uncle, and brother of the donor. It is a three-story building, the main portion of which is 170 feet long and 50 feet wide; it contains the machine shop and pattern shop, and a portion is used temporarily for the electrical laboratories.

The foundry and introductory engineering laboratory occupy a one-story building, 180 feet long and 40 feet wide.

The School of Electrical Engineering is housed in FRANKLIN HALL, but a portion of the electrical laboratory is temporarily situated on the second floor of Rand Hall.

LABORATORIES AND MUSEUMS

Civil Engineering

The Civil Engineering Laboratories are housed in four distinct buildings and comprise the following:

The Cement and Concrete Laboratory. This laboratory contains machines for tension tests, compression machines of from two to two hundred tons capacity, an impact machine and an eight-unit fatigue apparatus for repeated bending of concrete beams. For direct experiment with cement there is also provided a large number of tension and compression briquette molds, a water tank with capacity for the storage of three thousand briquettes, a moist cabinet with a capacity of seven hundred briquettes, and a Freas automatic electric drying oven; a Wagner turbidimeter; a moist curing room; a freezing room of 125 cu. ft. capacity with a temperature range of +70° to −17°F.; scales, slates, and plateglass mixing tables, thermometers, permeability apparatus, several sets of apparatus for measuring linear and volume changes during setting, and apparatus for determining specific gravity, normal consistency, time of set, and constancy of volume by normal and accelerated tests; also standard sieves for determining fineness, a Ro-Tap Testing Sieve Shaker, and apparatus for determining voids in sand and stone. Knock-down forms are provided for the molding of large concrete beams and columns, and an Austin Cube Mixer is available for making concrete.

The Testing Laboratory. The equipment of this laboratory includes a Riehlé 400,000-lb. testing machine with a capacity for beams and girders up to 19 inches in width and 18 feet in length, and for specimens in tension and compression up to 12 feet in length; a Riehlé 50,000-lb. testing machine; an Olsen 100,000-lb. testing machine; an Olsen 50,000-lb. testing machine, an Olsen 10,000-lb. wire testing machine; a Riehlé torsion testing machine of 60,000 inch-pounds capacity for testing rods and shafts up to one and a half inches in diameter and six feet in length; a Riehlé 5,000-lb. transverse load testing machine for flexural tests of bars of wood and metal up to four feet in length; a standard Page impact machine for tests of road material; a Riehlé grinder for stone specimens; a standard Deval machine for abrasion tests of road material; and a standard rattler for paving brick. The equipment also includes a set of torsion clinometers reading to single minutes for use with the Riehlé torsion machine; a Henning extensometer for tension tests of metals, and two self-indicating dial extensometers with fittings which adapt them for use in testing steel or iron tension or compression specimens, and also for testing full-sized concrete beams and columns and for tests of wire. Four Berry strain gages and a Whittemore strain gage are available for practical measurements of deformation of steel and concrete structures. The Martens mirror extensometer is also available.

THE MECHANICS LABORATORY. This laboratory is equipped with apparatus for qualitative and quantitative demonstration and experimentation by undergraduate students in the fundamental principles of dynamics and mechanics of materials, in conjunction with the classroom instruction in mechanics.

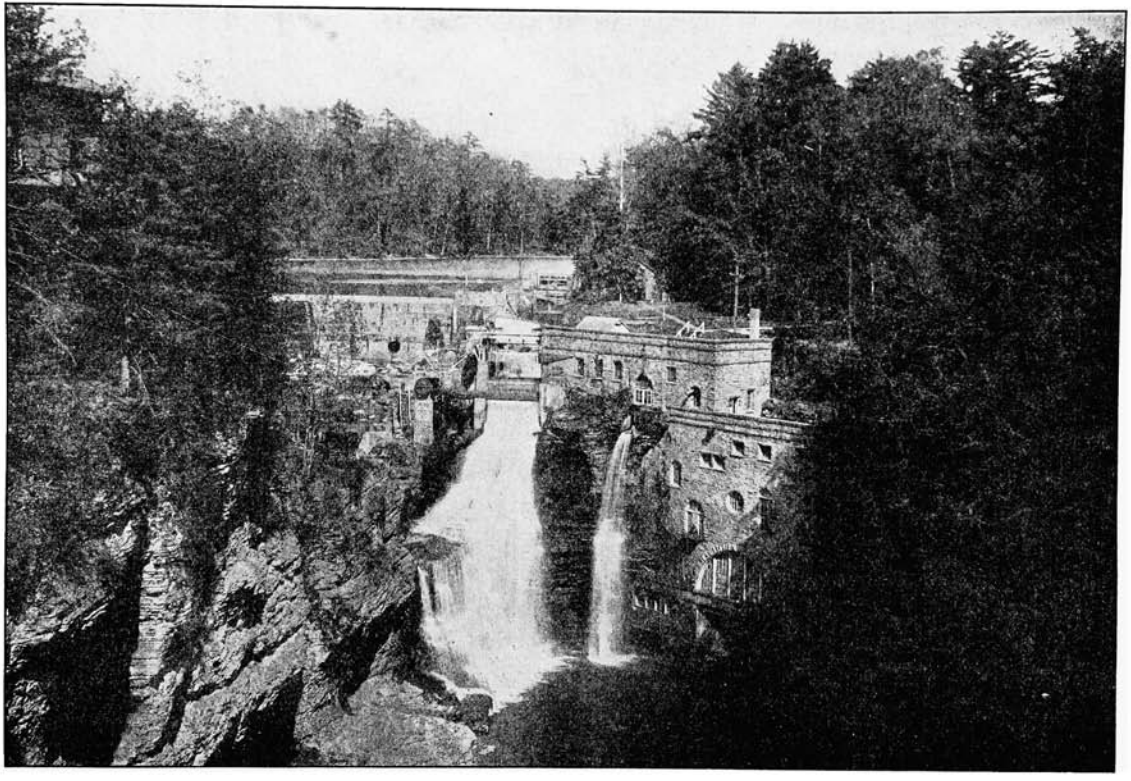
LABORATORY OF APPLIED ELASTICITY. There is recently installed a specially built photo-elastic apparatus providing a 12-inch diameter beam, suitable for a wide range of experimentation in advanced mechanics and structural analysis. The laboratory is also provided with electrical equipment suitable for investigations of seepage, hydraulic flow, certain stress problems, and other applications of the electrical-hydraulic, or electrical-stress, analogies based on the potential theory. A Beggs Deformeter is available for experimental analysis of statically indeterminate structures.

THE HIGHWAY LABORATORY. The laboratory is equipped with apparatus for making all the standard tests on non-bituminous and bituminous materials used in highway construction and maintenance and also for examining the properties of subgrade soils.

The section of the laboratory for testing non-bituminous materials such as gravel, rock, etc., is in the basement of Lincoln Hall. It is equipped with a Deval machine, core drill, rock saw, grinding lap, Page impact machine, ball mill, briquette molding machine, cementation testing machine, Dorry machine, rattler, and other accessories for conducting tests.

The laboratory for testing bituminous materials, bituminous mixtures, and subgrade soils is housed in a separate building. This laboratory is equipped with facilities for making the standard tests of specific gravity, consistency, ductility, softening point, total bitumen, etc., on bituminous materials and also with apparatus for the examination of bituminous mixtures determining the liquid limit, plastic limit, shrinkage determinations, wet and dry mechanical analysis, centrifuge moisture equivalent, etc., of subgrade soils.

THE HYDRAULIC LABORATORY. In addition to the usual equipment for the ordinary laboratory experiments, the unique location and construction of this laboratory render practicable investigations requiring a steady gravity water supply for long periods using relatively large flows of water. The water supply is obtained from Fall Creek with a water shed of 126 square miles. Beebe Lake, a pond of about 20 acres, has been formed by the construction of a concrete dam 26 feet high with a spillway crest length of 130.5 feet. At one end of the dam there is an additional flood spillway of 141.5 feet long. A rectangular canal 420 feet long and 16 feet wide is supplied from Beebe Lake through six headgates for controlling the amount of flow. The upper portion of the canal is 17.7 feet deep and the lower portion is 10 feet deep. In this canal are two sharp crested weirs 16 feet long over which discharges as large as 400 cubic feet a second may be



THE HYDRAULIC LABORATORY

passed. The lower portion of the large 16-foot canal, 350 feet long between weirs, is used for measurements with floats and current meters. Models of dams may be built in the canal and the flow over them investigated with precision. An electrically operated car spans this canal and is used for rating current meters and Pitot tubes and for experiments that require the towing of floating or submerged objects through still or running water at various speeds. By means of a gear system the speed of the cable which moves the car, may be varied through a range from ¼ to 12 feet a second. There are also two parallel concrete flumes with water supplied from Beebe Lake independently of the large canal. These are 2 feet wide, 2½ feet deep, and 90 feet long extending downstream from a short canal 7 feet wide, 3 feet deep, and 40 feet long near the dam, to a 2,000 cubic foot concrete measuring tank. Outdoor work is usually suspended from December 1 to April 1 because of the freezing weather.

The laboratory building is built against the south cliff of Fall Creek Gorge and extends vertically about 70 feet, from the pool below Triphammer Falls to the top of the gorge. A short branch canal six feet wide is housed by the upper portion of the laboratory building and may be supplied directly from Beebe Lake by means of a 48-inch cast-iron pipe line with a short 30-inch branch at its lower end. A 30-inch valve controls the flow from the 48-inch pipe into the 6-foot canal. The 6-foot canal discharges either to waste into the pool below Triphammer Falls (a sheer drop of 60 feet) or into the upper end of a steel stand-pipe 6 feet in diameter and 60 feet high. A suitable mechanism causes an instantaneous diversion of discharges as large as 60 cubic feet a second from the waste flume into the standpipe or vice versa. The 6-foot standpipe is provided at the bottom with a 36-inch discharge valve operated by hydraulic pressure. There is a float gage indicating accurately the height of the water surface in the standpipe, when used as a measuring tank. An independent 10-inch pipe line from the 30-inch pipe to the bottom of the laboratory supplies most of the pieces of apparatus used for class work and research. The 6-foot standpipe may also be used as a supply tank, water being supplied to it from either the 6-foot canal or the 10-inch pipe line. In the laboratory building there is also a concrete flume, 2 feet wide, 4 feet deep, and 25 feet long. Flows up to 11 cubic feet a second can be passed through this and measured volumetrically. This flume is arranged conveniently for experiments on small weirs, low-head orifices, etc. There are numerous flanged connections from 4 to 12 inches in diameter for the attachment of apparatus. The hydraulic machinery equipment at present includes only types of the turbine, Pelton-Doble wheel, Fitz Overshot wheel, multi-stage centrifugal pump and hydraulic ram, all arranged for testing.

The utility of this plant has been demonstrated by calls from all parts of the country for the performance of experiments of great importance. Among these may be mentioned the valuable results ob-

tained for the United States Deep Waterways Commission, the Michigan Lake Superior Power Company, the City of New York in connection with its water supply, and the United States Geological Survey.

HAROLD I. BELL RESEARCH FUND. In memory of her husband, Harold Ingersoll Bell, C. E., 1905, Mrs. Ellen Foster Bell in 1922 gave the University five thousand dollars to establish the Harold I. Bell Research Fund. The income of the fund is used to purchase equipment and supplies for research in the field of hydraulic engineering and related fields, under the direction of the School of Civil Engineering.

THE SANITARY LABORATORY. This laboratory provides facilities for the physical, chemical, bacteriological, and biological analyses of water and sewage, and for the performance of such other tests as will acquaint the student with current practice as affecting the control and operation of the various types of water purification and sewage disposal plants. The equipment includes microscopes and the necessary accessories for complete bacteriological and biological examinations of water; an autoclave, a hot-air sterilizer, one 37½° and two 20°C. incubators, a chemical balance, a United States Geological Survey turbidity rod and color standards; four experimental sand filters, fitted with loss of head gages, and providing for a total depth of sand and water of nine feet, for determining the rate and efficiency of operation of sand filters, as well as various types of sewage nozzles. The laboratory is well equipped with such glassware, reagents, accessories, and apparatus as are needed for making the chemical analyses of water and sewage affluents.

THE FUERTES ASTRONOMICAL OBSERVATORY is situated north of Beebe Lake. It contains a transit room with four piers, a clock vault, a photographic darkroom, an office, a computing room, a classroom, and a dome for the 12-inch equatorial telescope, in addition to a comparator room and a constant temperature room for geodetic laboratory work. Besides the Irving Porter Church Telescope, a very superior 12-inch equatorial, the equipment includes a Howard mean time astronomical clock, chronometers by Negus and Nardin, four chronographs, a Troughton and Simms transit, two Fauth prismatic transits with latitude levels, a Fauth zenith telescope, an altazimuth by Troughton and Simms, spherometer, level-trier, and various meteorological instruments.

Facilities are provided for work along the various lines relating to geodesy and advanced surveying, including geodetic astronomy. The standards of length include: Invar tapes standardized at the U. S. Bureau of Standards; a steel meter bar of the International type which has been compared with the International Prototype Meter of the U. S. Bureau of Standards; a Rogers speculum metal decimeter and 4-inch scale, combined, accurately divided and compared; and a 4-meter bar for subsidiary measures. The laboratory equipment

also includes a Mendenhall half-second pendulum apparatus for the determination of the acceleration of gravity—the standard type used by the U. S. Coast and Geodetic Survey; a Kew magnetometer, a dip circle, and a declinometer, for observation of terrestrial magnetism; a dividing engine by the Société Genévoise; precision thermometers by Tonnelot and Boudin standardized at the International Bureau in Paris; a small comparator for calibrating thermometers; and the usual auxiliary apparatus. A 100-foot tape comparator is located on the fourth floor of Lincoln Hall.

Mechanician's Room. This room is used in connection with the laboratories for the construction of special apparatus and instruments and for the maintenance of the equipment. It is well supplied with tools and special machines for the purpose, and is in charge of a mechanician.

The Museums and Drawing Rooms of the School of Civil Engineering contain the following collections: (1) The Muret collection of models in descriptive geometry and stone cutting. (2) The DeLagrave general and special models in topography and geology. (3) The Schroeder models in descriptive geometry and stereotomy with over 50 brass and silk transformable models made in the school after the Olivier models. (4) The M. Grund collection of bridge and roof details, trusses, and masonry structures, such as right, oblique, and annular arches and domes, and several intricate models in stone cutting, supplemented by similar models by Schroeder and other makers. (5) A model railroad bridge of 25-foot span, one-fourth natural size, and a numerous collection of models of track details. (6) The Digeon collection of movable dams, artificial harbors, and working models in hydraulic engineering. (7) Working models of water wheels, turbines, and other water engines. (8) Several large collections of European and American progress photographs of engineering work showing the progress of construction, and many other photographs, blue-prints, models, and diagrams. (9) A collection of typical geodetic and surveying instruments of historical interest, including a secondary base-line apparatus made under the direction of the United States Coast and Geodetic Survey, a pair of base-bars constructed in this school, solar and magnetic compasses, levels, transits, theodolites, omnimeters, tacheometers, sextants, telemeters, altmeters, hypsometers, odometers, meteorological instruments, etc., with a large number of auxiliary and special instruments such as planimeters, pantographs, elliptographs, calculating devices, and computing machines.

The Laboratories of Mechanical Engineering

The Mechanical Engineering Laboratories and Work Shops comprise the following:

The Materials Testing Laboratory. This laboratory is equipped for tension and compression tests with an Olsen 300,000 lb.

machine, a Riehlé 100,000-lb. machine, a 200,000-lb. Emery hydraulic machine, an Olsen 150,000-lb. three-screw machine, an Amsler 100,000-lb. hydraulic machine, together with several other machines varying in capacity from 10,000 to 100,000 pounds. For transverse test there is a Riehlé machine of 200,000 pounds capacity and a Fairbanks machine of 10,000 pounds capacity. There are one Thurston autographic torsion machine, one Olsen torsion machine of 200,000 inch-pounds capacity, two Upton-Lewis fatigue testing machines, and an Amsler-Charpy-Izod impact testing machine. The equipment includes hardness testing machines, extensometers, a cathetometer, gas furnaces, tempering baths, and all other apparatus required for the determination of the physical qualities of engineering materials under tensile, compressive, transverse, and torsional stress, and under different kinds of heat treatment.

The Photo-Elastic Laboratory. A Bausch and Lomb polariscope with 5″ diameter beam is the basis upon which this laboratory has been built up. Material for the construction of models is on hand, as well as equipment for polishing and annealing. A 2,000-lb. Olsen Universal hydraulic testing machine is used for loading the models. Both white light and monochromatic light sources are available. Stress distributions in models up to 12″ in length or breadth can be determined.

The Steam Laboratory. In this laboratory there is a 150-HP triple expansion Allis-Corliss engine so fitted up that it may be operated as a simple, compound, or triple expansion engine, condensing or non-condensing. There are also several smaller engines, including a Russell, a Harris-Corliss, a Payne, a Fitchburg uniflow, and a Troy steam engine. There are three surface condensers and one jet condenser which may be connected with these engines as desired. There are two 35-kw. horizontal Curtis turbines, and a 15-kw. De-Laval turbine which drives electric generators and may be run condensing or non-condensing, and a Lee turbine driving a Goulds centrifugal pump. A two-stage Worthington air compressor driven by a Uniflow engine and one airbrake pump, together with meters, nozzles, and other instruments, may be used for routine tests. This part of the laboratory also has several fans that can be arranged and equipped for testing. The apparatus and instruments used for engine testing comprise about eighty indicators of different types, about seventy-five stream gauges, a number of calorimeters for determination of the quality of steam, speed counters, tachometers, planimeters, etc., besides a number of dynamometers of various kinds. The boiler section of this laboratory has one 150-HP Babcock and Wilcox water-tube boiler of the marine type, one 100-HP Babcock and Wilcox water-tube boiler of the standard type, both of which are fitted with internal superheaters, and an 80-HP Heine water-tube boiler. The auxiliary apparatus consists of a Cochrane open heater, a Wain-

wright closed heater, steam pumps, traps, injectors, etc. A full set of scales, measuring tanks, gauges, flue gas apparatus, separating and throttling calorimeters, pyrometers, etc., complete the boiler equipment.

THE GAS ENGINE LABORATORY. The equipment in this laboratory is chosen with a view to providing a great variety of types as to fuel used, governing, etc. It includes an 8-HP Fairbanks gasoline engine, an 8-HP Olds gasoline engine, a 6-HP Ingeco oil engine, a 6-HP and a 15-HP Hornsby-Akroyd oil engine, a 30-HP Westinghouse gas engine, a 25-kw. General Electric Co. gas motor set, and a 45-HP Diesel engine. High speed engines are represented by a variety of auto and airplane engines. The testing equipment includes a full set of indicators and a Midgley indicator. Dynamometers are represented by a 150-HP Sprague Electric, a 60-HP Diehl Electric, a 150-HP General Electric, a Wheeler hydraulic, good for 100-HP at 4000 r.p.m., and a second Wheeler dynamometer, good for 300-HP at 2500 r.p.m.

THE HYDRAULIC LABORATORY. This laboratory contains the following machines and apparatus: a 6-inch single-stage DeLaval centrifugal pump; a 2½-inch two-stage Worthington centrifugal pump, a 16-inch Goulds centrifugal pump direct connected to a variable speed motor; a 12-inch Doble water wheel; a 15-inch S. Morgan Smith turbine with Lombard governor; a complete test stand for research and testing of pumps in capacities up to 1000 G.P.M. and 230 ft. head at speeds up to 4000 r.p.m., including two electric dynamometers of 13-HP and 3-HP rating with independent motor-generator power supply and control, a 3-inch motor-driven centrifugal booster pump and 1½-inch motor-driven centrifugal priming pump, 2-inch, 3-inch and 4-inch calibrated Venturi tubes; Toledo Precision platform scales with tank for the collection and weighing of water in amounts up to 6500 lbs.; sets of weir boxes with various types of weirs and nozzles for the determination of coefficients of discharge; various types of water meters and other apparatus for measuring the flow of water, such as Pitot tubes, Venturi meters, current meters, etc.

THE OIL TESTING LABORATORY. This laboratory contains a Cornell oil-testing machine, a Thurston standard railway-testing machine, and several smaller Thurston machines. The rest of the equipment consists of several viscosimeters of different types, flash and burning test apparatus, together with the necessary hydrometers and thermometers.

THE REFRIGERATION LABORATORY. For the study of refrigeration the mechanical laboratory possesses a 2-ton York absorption machine and a very complete York refrigerating compression plant having a capacity of 15 tons of ice.

THE CEMENT LABORATORY. This laboratory not only contains the ordinary apparatus for the testing of cement and concrete, but in addition is equipped with crushing and grinding machinery and a

RAND HALL

Containing the Machine Shop, the Pattern Shop, and an Electrical Laboratory

small vertical kiln for making investigations on the manufacture of cement from raw material.

THE FUEL TESTING LABORATORY. This laboratory contains a complete equipment of fuel calorimeters and other apparatus needed for the determination of the composition and calorific value of fuel, whether gaseous, liquid, or solid.

THE BELT TESTING LABORATORY. This laboratory contains a belt testing machine which consists of two 75-HP electric dynamometers capable of operating at any speed up to 1000 r.p.m. and of carrying pulleys up to 36 inches in diameter. The belt tension power transmitted by the belt, and the slip of the belt may be observed. Belts can be tested in widths up to 10 inches and the pulley center distance may be varied from 4½ feet to 20 feet.

AERONAUTICAL EQUIPMENT. Laboratory and field work in aeronautics is conducted with the cooperation of the management of the Ithaca airport. The college has laboratory facilities for calibration of aeronautical instruments in connection with flight tests run at the Ithaca airport. Most of the publications of the National Advisory Committee for Aeronautics are available in the library.

The Work Shops of the Sibley School of Mechanical Engineering comprise the following units:

THE FOUNDRY occupies floor space of about 4,800 square feet, and has an equipment for the production of iron and composition castings. The methods of producing duplicate work are demonstrated by molding machines of different types selected to illustrate the production of castings of various kinds at lowest labor cost.

THE PATTERN SHOP occupies the top floor of Rand Hall with floor space of 8,440 square feet. The work given the students in this department includes the use of hand and power operated tools under instructors who are skilled in the trade of pattern making.

THE MACHINE SHOP is located on the ground floor of Rand Hall with the same floor area as the pattern shop. It is equipped with an electric traveling crane and representative modern machine tools selected with a view to demonstrating manufacturing methods. A part of the work-shop equipment is installed to illustrate the latest practice in production with specialized labor-saving machinery. The students are not expected to become skilled operators of the machines of this class, but to acquire a general knowledge of their possibilities in the kinds of work to which they are adapted. The equipment is arranged in groups, each under the charge of an instructor who has made a special study of the machinery in his group.

THE INTRODUCTORY ENGINEERING LABORATORY contains the necessary equipment to demonstrate the principal operations in the forge shop, forging (hand and machine), welding, soldering, brazing, etc. The equipment also includes numerous examples of common

engineering appliances such as valves, traps, gages, etc., and an example of simple steam engine, a gas engine, and a steam pump. There is also a complete equipment to teach the principles of oxy-acetylene welding and cutting; electric arc welding, and atomic hydrogen arc welding.

The Laboratories of Electrical Engineering

The equipment of the laboratories of the School of Electrical Engineering is distributed as follows:

The Lecture Equipment. The main lecture room is on the first floor of Franklin Hall. Provision is made here for a large number of experimental demonstrations which accompany many of the earlier lectures in electrical principles and electrical machinery.

Direct and alternating current power from the University Gorge Plant is available here at a two-panel switchboard so located as to be seen from all seats. The direct current panel is also connected with the Dynamo Lab., which provides adjustable 110 and 220 volts for two and three-wire services. The alternating current panel provides 110 and 220 volts for single phase and three-phase services.

The switchboard carries two large Western D'Arsonval type meters with multi-range plugs, and for a.c. the usual dynamometer-type indicating meters. Plug terminals are provided for any desired connection of all meters. Synchronizing lamps are mounted in the a.c. panel.

A three unit set made up of a compound direct current machine, an induction motor, and a synchronous machine is mounted on a semi-portable table. Accessory and control equipment are also mounted on the table. Provision is made for making connections from this table to the main switchboard and to the lecture demonstration table.

Electrical Machinery Laboratories: A great variety of direct and alternating-current machines are available, so selected as to afford at least one machine of every type ordinarily encountered in practice. Most of these represent modern construction and are of such size and design as to give typical performance, but at the same time provision is made for great flexibility of operation. For example, in five of the synchronous machines the coil terminals are brought out to an external connecting board. One 15-kva synchronous machine is, in addition, provided with a phase-wound rotor and a squirrel-cage rotor, either of which may be readily used to replace the synchronous rotor. A modern type of synchronous converter is arranged for direct or inverted operation, either single-phase, two-phase, or three-phase, with metering and control boards which permit very rapid change of operating conditions. There are three types of commutating alternating-current motors, four types of fractional-horsepower alternating-current motors, and a large number of direct-current machines.

Typical examples of automatic starters for alternating and direct current motors are provided, including time-element, counter-e.m.f., and series lock-out types, in addition to drum controllers and a complete Sprague multiple-unit railway control system.

The non-rotating apparatus also includes constant-potential transformers of standard and special construction, constant-current transformers, induction regulators, storage batteries and a small mercury-arc rectifier.

The facilities for testing are well-planned and very complete. For machine testing, there are numerous Prony brakes, and electric dynamometer, and a special apparatus for determining the complete characteristics of fractional-horsepower motors. The magnetic testing apparatus includes a Fahy permeameter, an Epstein apparatus and a large motor-generator set comprising two sine-wave generators and a third-harmonic generator on the same shaft, with provision for adjusting phase displacement and for measuring form factor. The dielectric testing apparatus includes an 80,000-volt testing transformer together with full-wave rectifying equipment and an electrostatic voltmeter. Among the general pieces of test equipment are a very complete assortment of meters and three oscillographs.

THE STANDARDIZING LABORATORY includes standard precision ammeters and voltmeters, a Silsbee current-transformer test set, and primary standards of voltage and resistance with the necessary potentiometers and auxiliary equipment arranged for convenient checking of secondary standards and of other meters.

THE ELECTRICAL COMMUNICATION LABORATORY. This laboratory is well equipped with apparatus to illustrate present day methods of electrical communication. The wire telegraph section includes various types of commercial apparatus illustrative of simple, duplex, quadruplex, and repeater circuits. The telephone section includes representative telephone equipment of various types. A complete machine switching exchange is installed in the laboratory. The radio section comprises various transmitting and receiving sets including a complete commercial radio broadcasting equipment. Laboratory standards of inductance, capacity and frequency are available for precision tests and measurements.

LIBRARIES: GENERAL AND DEPARTMENTAL

The Cornell University Library comprises about 877,000 volumes, being one of the largest collections of its kind in the country. Most of the books are in a general library building.

For convenience of reference, the University Library maintains DEPARTMENT LIBRARIES—in Lincoln Hall for the School of Civil Engineering, in Sibley Dome for the School of Mechanical Engineering, and in Franklin Hall for the School of Electrical Engineering. These libraries are under the supervision of the authorities of the

several schools. They contain the standard reference and text books and the current files of the important engineering periodicals.

Of special importance is the KUICHLING MEMORIAL LIBRARY, of the School of Civil Engineering, a collection of about fifteen hundred books and pamphlets on hydraulic and municipal engineering, formerly the professional library of the late Emil Kuichling, A.B., C.E., of Rochester, N. Y. It was given to the school in 1919 by Mrs. Sarah L. Kuichling, with an endowment of one thousand dollars, the income of which is to be used to extend the collection and to maintain it as a separate library.

Through the generosity of former students in the School of Civil Engineering, the Irving Porter Church Fund was established in 1917 for book purchases for the School's Library.

The library in Franklin Hall for the School of Electrical Engineering is known as the ALEXANDER GRAY MEMORIAL LIBRARY. The nucleus of the library was the personal library of the late Alexander Gray, for some years Professor of Electrical Engineering at Cornell University and executive head of the School of Electrical Engineering. The McGraw Hill Book Company bought this collection and gave it to Cornell University for the use of the School of Electrical Engineering.

SCHOLARSHIPS: PRIZES: LOANS

The University has no means of remitting the usual tuition charges in any instance except to students of certain classes which are exempted by statute of New York State or the Board of Trustees. Those classes are defined in the General Information Number. There are no undergraduate tuition scholarships available to residents of the State of New York except the Padgham Scholarship (which is described below) and the Cornell Tuition Scholarships, which are awarded annually by the State Commissioner of Education after a competitive examination; and there are none available to non-residents of the State.

More particular information is given about undergraduate scholarships and loans in the General Information Number; about graduate scholarships and fellowships in the Announcement of the Graduate School and page 115 of this pamphlet; and about prizes in a pamphlet entitled Prize Competitions. Any of these publications may be obtained from the Secretary of the University.

UNDERGRADUATE SCHOLARSHIPS

George W. Lefevre Scholarships: Five awarded annually, each having an annual value of $400 and tenable each year so long as the holder remains in good standing in the University; only those candidates are eligible who furnish proof of their financial need. See the General Information Number.

The Cornell Tuition Scholarships: Open only to residents of the State of New York; awarded by the State Commissioner of Education. For particulars, see the General Information Number.

The University Undergraduate Scholarships: Eighteen awarded annually, each paying $200 a year for two years; awarded by the University each year to members of the incoming freshman class. For particulars, see the General Information Number.

The Eudorus C. Kenney Scholarships: Two awarded annually, each paying $250 a year for four years; open annually, to *bona fide* residents of the town of Truxton, Cortland County, New York; in case of a vacancy in any scholarship the value of the scholarship may be awarded by the University Faculty's Committee on Scholarships in such manner as it may deem best. For particulars, see the General Information Number.

UNDERGRADUATE SCHOLARSHIPS IN ENGINEERING

The John McMullen Scholarships: Open to undergraduates in Civil, Mechanical, or Electrical Engineering. These scholarships were founded by a bequest of John McMullen of Norwalk, Conn., to Cornell University "for the purpose of creating and maintaining free scholarship or scholarships for the education of young men as engineers, the details as to the amounts of said scholarships and the qualifications of the beneficiaries to be left to said institution to determine, said scholarships to be known as the John McMullen Scholarships." With the avails of this bequest the Board of Trustees has established at the present time a considerable number of undergraduate scholarships of an annual value of $200 each, and divided them among the three schools of the College of Engineering. Applications should be made to the Director of the school concerned.

The Frank William Padgham Scholarship, founded by Amos Padgham of Syracuse, New York, in memory of his son, Frank William Padgham, M.E. '88, entitles the holder to free tuition and fees in the regular courses in the Sibley School of Mechanical Engineering or in the School of Electrical Engineering. It cannot be held in connection with a New York State Scholarship. It will be

awarded to the candidate, if any, who has had his preparatory education in the public schools of Syracuse, New York, and who, having been admitted to the regular course in either of the Schools named, shall be approved by the University Faculty's Committee on Undergraduate Scholarships. If no candidate from the schools of Syracuse applies, the scholarship may be awarded to a student who has received his preparatory education elsewhere. Application should be made to the Dean of the College of Engineering.

THE FRED LEWIS WILSON SCHOLARSHIP: Open to undergraduates in Mechanical or Electrical Engineering. Mrs. Mary Northrup Wilson bequeathed Cornell University about $4,000 to found and perpetuate one or more scholarships in honor of her son, Fred Lewis Wilson, who was graduated from Sibley College with the class of 1892. These scholarships are awarded, for a period of not more than two years each, to undergraduates who have been at least one year in the University, under the following rule: "Scholarships arising out of this bequest shall be awarded by a committee consisting of the President of the University, the Dean of the College of Engineering, and one other person chosen by them; and in making such awards the following attributes shall be given the weight indicated; scholarship, evidenced by written examination, 30 per cent; character, in the broadest sense, 30 per cent; probable usefulness in the world at large, 30 per cent; proficiency in mechanic arts, 10 per cent; it being understood that these scholarships are intended to assist such students as are in need of financial aid to complete their courses."

THE JOHN LEISENRING WENTZ SCHOLARSHIP: Open to undergraduates in Mechanical or Electrical Engineering; consists of the income of a fund of $5,500, given the University in 1920 by Mrs. Lewis Audenried in memory of John Leisenring Wentz, a member of the class of 1898. It is awarded at the end of each academic year to a member of the incoming senior class who is in need of pecuniary aid; the beneficiary must have maintained a high scholastic standing during his junior year. The award is determined by a committee approved by the President of the University from the Faculty of the College of Engineering, and is reported to the University Faculty for the purpose of record.

THE WILLIAM DELMORE THOMPSON SCHOLARSHIP: Open only to undergraduates in Mechanical Engineering; established in memory of William Delmore Thompson of the class of 1918; pays $40 a year and is for the benefit of self-supporting students of mechanical engineering. It is awarded at the beginning of the junior year, and if the student's work proves satisfactory it is continued through the senior year.

THE JUDSON N. SMITH SCHOLARSHIP: Open to upperclassmen in the School of Civil Engineering; pays $160 a year, the income of a fund given by Mrs. Sarah L. Smith of Saranac Lake, New York, in memory of her son. It is awarded by the Faculty of the School of Civil Engineering at the end of each year to a student of the incoming senior or junior class in that school, of good character and scholarship and needing pecuniary aid. Applications must be made before May 1.

THE MARTIN J. INSULL SCHOLARSHIP FUND was founded in 1929 by Mrs. Martin J. Insull in honor of her husband, Martin J. Insull, M.E. '93, to enable a deserving student or students to pursue a regular undergraduate course of study in the College of Engineering. The persons eligible must be young men of good character who have presented acceptable credentials for admission to the entering class of the College of Engineering, whose preparatory work has given evidence of capability for advanced technical training, and who can not afford a college education. The Scholarship shall be tenable during regular attendance, good behavior, and good academic standing, and may be withdrawn for failure in any of these respects. The President of the University shall award the Scholarship to an eligible candidate nominated by the Dean and the Directors of the College of Engineering. Applications, with certificates in regard to eligibility for the Scholarship, should be made to the Dean of the College of Engineering not later than July 1. Not available in 1935-36.

OTTO M. EIDLITZ SCHOLARSHIPS: Open to undergraduates in the College of Engineering. These scholarships were founded in 1929 by a bequest of Otto

M. Eidlitz, C.E. '81, of $25,000 to Cornell University to establish a scholarship fund in the College of Engineering for students who require financial assistance. With the avails of this bequest three scholarships of an annual value of $325 have been established. These scholarships are awarded by the Dean of the College of Engineering to such students as appear to be most deserving because of their character and intellectual promise.

THE SYLVESTER EDICK SHAW SCHOLARSHIP, the income of a fund of $4,000 given in 1929 by Sylvester Edick of Newfane, is awarded to a student designated by the alumni of Cornell University who are residents of Niagara County at the time of the award. If the alumni fail to make such designation, the award is made by the principal of the Lockport High School, preference being given to the student who is most in need of financial assistance and who is studying Mechanical or Electrical Engineering. The student has the benefit of the scholarship for the entire period of his course, provided his conduct and progress in his work are satisfactory.

THE JOSEPH N. EVANS SCHOLARSHIP, consisting of the annual income from a bequest of $3,000 given by the will of Mrs. Joseph N. Evans in memory of her husband. Open to any undergraduates in the College of Engineering upon application to the Dean.

PRIZES IN THE COLLEGE OF ENGINEERING

THE FUERTES MEDALS: Established by the late Professor E. A. Fuertes; two gold medals, each of the value of one-half the amount of income provided by the endowment fund. One of these medals is awarded annually by the University Faculty to that student of the School of Civil Engineering who is found at the end of the first term of his senior year to have maintained the highest degree of scholarship in the subjects of his course, provided he has been in attendance at the University for at least two years; the other medal is awarded annually by the Faculty to a graduate of the School of Civil Engineering who has written a meritorious paper upon some engineering subject tending to advance the scientific or practical interests of the profession of the civil engineer. It is desired that papers be presented on or before April 15. If a paper is presented in printed form, it will not be received if it has been printed earlier than the next preceding April 15. Neither medal is awarded unless it appears to the Faculty of the School of Civil Engineering that there is a candidate of sufficient merit to entitle him to such distinction. Candidates are recommended to the University Faculty by the School of Civil Engineering annually.

THE FUERTES MEMORIAL PRIZES IN PUBLIC SPEAKING: Founded by the late Charles H. Baker, a graduate of the School of Civil Engineering of the class of 1886. Three prizes, one of $100, one of $25, and one of $15, are awarded annually to members of the junior and senior classes in the Colleges of Engineering and Architecture, for proficiency in public speaking. The conditions of the award are as follows: (1) The competition shall be open to seniors and juniors in the Colleges of Engineering and Architecture. (2) The competition shall be held on the evening of the third Friday in April. (3) A preliminary contest shall be held before a committee of four, representing each of the three Schools of Engineering and the College of Architecture, at such time and place as this committee may decide. Each contestant in this preliminary contest shall (a) submit a letter of not more than 400 words outlining the purpose and argument of his proposed address; (b) speak from a platform, without notes, for not more than five minutes, either on the subject of the proposed address or on some other subject, at the contestant's option. From the contestants at this preliminary contest not more than seven candidates shall be selected by the committee for the final contest. (4) The speeches delivered in the competition must be on technical subjects original in character. Any technical subject may be chosen by the competitor that may seem to him best suited to furnish an opportunity for persuasive argument. Questions relating to his profession that would naturally come before semi-technical or non-technical commissions, boards of directors, and conventions are of

peculiar fitness. In making the award, both the character of the argument and the manner of presentation shall be considered. Each speech shall be limited to fifteen minutes. (5) The delivery must be without notes, but illustrative materials such as diagrams, plans, models, or lantern slides may be used. (6) The judges of the final contest shall be six in number—one selected by the College of Architecture, one selected by each of the three Schools of the College of Engineering, one selected by the Department of Oratory and one selected by the President of the University from men prominent in business life in the city of Ithaca. (7) A student who has already received the first prize is not eligible for subsequent competition.

THE CHARLES LEE CRANDALL PRIZES: Founded in 1916 by alumni of the School of Civil Engineering; prizes of $75, $50, $35, and $20. They are awarded each year, by a committee appointed by the Director of the School of Civil Engineering, for the best paper written by seniors or juniors in that school on suitable subjects, provided both the substance and the written form of the papers submitted show real merit. If, in any year, no papers of sufficient merit are presented for these prizes, the income from the fund for that year is added to the principal and the additional income used from time to time to increase the amount of the prizes. The fund was established to provide prizes to encourage original research, to stimulate interest in matters of public concern, and to inspire in the students an appreciation of the opportunities which the profession of civil engineering offers them to serve their fellow men as intelligent and public-spirited citizens. Papers must be submitted to the Director of the School of Civil Engineering on or before May 1 of each year.

THE SIBLEY PRIZES IN MECHANIC ARTS: Awarded to undergraduates in Mechanical or Electrical Engineering. Under a gift of the late Hiram Sibley, made in 1884, the sum of one hundred dollars is awarded annually in five prizes to juniors and seniors in the School of Mechanical Engineering and in the School of Electrical Engineering who have received the highest marks in scholarship in at least three full terms of work required in the course and done in the schools named. The prizes are $30, $25, $20, $15, and $10.

THE J. G. WHITE PRIZE IN SPANISH. Through the generosity of James Gilbert White (Ph.D., Cornell, '85) three prizes, established in 1914, each of the value of $100 are offered annually. One of the three, which is awarded to an English-speaking student for proficiency in Spanish, is open to members of the junior and senior classes in the College of Engineering, who are candidates for their first degree. No candidate is eligible unless he has completed successfully two terms of work in Spanish at Cornell University. The prize is awarded mainly on the basis of linguistic attainments, in determining which a general knowledge of the language, including its grammar and literature, counts one-half, and ability to speak the language fluently and correctly counts one-half. For further details consult "Prize Competitions," a pamphlet published by the Secretary of the University.

THE ROBERT HARRIS SIMPSON PRIZE: Founded in 1933 by Mrs. Simpson in memory of her late husband, Robert Harris Simpson, C.E. '96. This prize of $25 will be awarded annually to that senior in the School of Civil Engineering who submits the best technical description or design of a civic improvement of sufficient substance and merit to justify the award. Papers or designs must be submitted on or before May 1 of each year, and will be judged by a committee appointed by the Director of the School of Civil Engineering.

LOAN FUNDS: AWARDS: OTHER PECUNIARY AIDS

Cornell University has two general funds that are used to make loans to students. They are (1) the F. W. GUITEAU STUDENT LOAN FUND, established by the will of Frederick William Guiteau and augmented by the will of his sister, Mrs. Nancy Guiteau Howe, both of Irvington-on-Hudson, the income of which fund is by the terms of the bequest available for loans to young men; and (2) THE WOMEN STUDENTS' LOAN FUND, consisting of a former student loan fund, increased in 1913 by $7,000 assigned to this fund by the late President Andrew D. White from funds placed at his disposal by the late Trustee Andrew Carnegie.

Both these funds are administered for the Trustees of the University by a standing committee. Applications for loans are received by the Secretary of the University for submission to that committee. The benefits of these funds are reserved to undergraduate students who have been in attendance at Cornell University for at least one year, and preference is given to seniors and juniors. Account is taken of the applicant's character, scholastic record, and need of financial assistance. Loans are made ordinarily to assist students who would otherwise be unable to meet the tuition charges. The student must not regard the loan fund as a normal or assured resource. No student should enter upon a year at the University with the expectation of paying a part of the year's expenses with money yet to be borrowed. The use of the loan fund is a privilege reserved to the industrious student of proved merit and earning power whose means are so nearly exhausted and whose training is so nearly completed as to warrant going into debt in order to complete the training without delay. Money borrowed from either of the funds is to be repaid to the fund with interest at five per cent. per annum.

The Wurts Loan Fund, the gift of Alexander Jay Wurts, in memory of his mother, Laura Jay Wurts, was founded in 1912 to assist needy students of the two upper classes in the Sibley School of Mechanical Engineering. Upon the recommendation of the Dean of the College of Engineering, loans from the income of this fund may be awarded by the Faculty of the College of Engineering, with the approval of the Treasurer, to one or more students each year.

The Alan Park Toms Award was founded in 1924 by Dr. and Mrs. S. W. S. Toms in memory of their son, Alan Park Toms, M.E., 1923, who lost his life in an untimely manner while practicing his profession. The value of the award is about $250 annually and is available only for undergraduates in the Sibley School of Mechanical Engineering. Awards from this fund are made on the recommendation of the Dean of the College and the Director of the Sibley School of Mechanical Engineering and with the approval of the Faculty of Engineering to one or more worthy students each year.

The Carl Richard Gilbert Award was founded in 1929 by Mr. and Mrs. A. S. Gilbert in memory of their son, Carl Richard Gilbert, who died during his Junior year. The value of the award is about $190 annually and is available for students in the School of Electrical Engineering. Awards from this fund are made on the recommendation of the Dean of the College and the Director of the School of Electrical Engineering, and with the approval of the Faculty of Engineering, to one or more worthy students each year.

The Martin J. Insull Loan Fund was founded in 1924 by Martin J. Insull, M.E., '93, of Chicago, to be used for making loans to deserving students in the Sibley School of Mechanical Engineering who have been pursuing their studies there for at least one year. Loans are made on the unsecured promissory note of the student borrowing, bearing five per cent. interest annually, and payable within three years from the time the borrower leaves the University through graduation or otherwise. This fund is administered for the Trustees by the University's standing committee on loans, and applications are received by the Secretary of the University for submission to that committee.

The Robert Critchlow Dewar Loan Fund, the joint gift of Mrs. James M. Dewar and the Cornell Society of Civil Engineers, in honor of Robert Critchlow Dewar, C.E., 1909, who lost his life in the performance of his duties as a civil engineer, is available for undergraduates in the School of Civil Engineering upon recommendation of the Director of that school.

The William C. Seidell Book Fund of $1,000 was founded by Gerrit S. Miller. The income is used for the purchase of books for young men who are working their way through the School of Civil Engineering, and is paid by the Treasurer of the University upon the recommendation of the Director of the school, preference being given to underclassmen.

The Cornell Clubs of Buffalo and Rochester have each made provision for the loan of a small sum of money each year to an undergraduate student coming from the club's own neighborhood.

ADMISSION TO THE COLLEGE

All correspondence concerning admission to the College of Engineering should be addressed to The Director of Admissions, Cornell University, Ithaca, N. Y., who will forward the necessary blank form of application on request. All credentials relating to the admission of a new student should be sent to the Office of Admissions as early as possible, in no case later than the first day of September. A prospective applicant should read carefully the paragraph headed Rules Governing Admission, a page or so further on. He should also read the General Information Number, for which application should be addressed to The Secretary, Cornell University, Ithaca, N. Y.

ADMISSION TO THE FRESHMAN CLASS

The Requirements for Entrance to the Regular Four-Year Course

For admission to the freshman class in the regular four-year course, the applicant must offer fifteen specific units of entrance subjects, as follows: English, 3 units; History, 1 unit; Elementary Algebra, 1 unit; Intermediate Algebra, 1 unit; Plane Geometry, 1 unit; Solid Geometry, ½ unit; Plane Trigonometry, ½ unit; foreign language equivalent to 3 units in either Greek, Latin, German, French, Spanish, or Italian, or 2 units in each of two of them; and in other entrance subjects, elected by the applicant, 3 or 4 units. Applicants offering fifteen units which do not differ materially from the specific list may present their credentials for consideration.

It is recommended that French or German be offered to satisfy the language requirement for the reason that a knowledge of either of these tongues gives the student immediate access to a large part of the standard literature in the theory and practice of engineering.

The student preparing to enter the college is strongly advised to offer at least three of his elective units in Language and History. His work in the four-year course in engineering will necessarily be almost entirely scientific or technical and will leave him little opportunity for instruction in other fields. He will do well, therefore, during his preparatory years, to avoid unnecessary specialization and to make his studies as liberal as possible. Applicants who have not had this broader education are recommended to take either a five-year course or a six-year course, if they can afford the additional time and expense involved.

Students who have had some practical experience in engineering usually gain more than others from the courses offered by the College of Engineering; hence it is recommended that prospective students spend at least one summer vacation in practical work in connection with some kind of engineering.

The applicant must be at least sixteen years of age. Under special circumstances the committee on admissions will admit students who lack not more than one-half unit in Advanced Mathematics, (Solid Geometry, Plane Trigonometry), if fifteen units are offered and all other requirements are met. Such students may so arrange the course as to graduate in four years plus attendance in one Summer Session. More detailed information about courses requiring more than four years for graduation will be furnished upon application to the Secretary of the College of Engineering.

SUBJECTS THAT MAY BE OFFERED FOR ENTRANCE

The subjects that may be offered for admission to the College of Engineering are named in the following list. The figure in parenthesis opposite the name of each subject indicates its value expressed in units and shows the maximum and minimum amount of credit allowed in that subject. A unit represents a year's study in any subject in a secondary school, constituting approximately a quarter of a full year's work. Two hours of laboratory work are counted the equivalent of one hour of prepared recitation, but in Drawing or Manual Training 300 hours of actual work are required for one unit. If an applicant counts Biology (1) he may not also offer Botany (½) or Zoology (½).

1.	English	(3)
2a.	First Year Greek	(1)
2b.	Second Year Greek	(1)
2c.	Third Year Greek	(1)
3a.	First Year Latin	(1)
3b.	Second Year Latin	(1)
3c.	Third Year Latin	(1)
3d.	Fourth Year Latin	(1)
4a.	First Year German	(1)
4b.	Second Year German	(1)
4c.	Third Year German	(1)
4d.	Fourth Year German	(1)
5a.	First Year French	(1)
5b.	Second Year French	(1)
5c.	Third Year French	(1)
5d.	Fourth Year French	(1)
6a.	First Year Spanish	(1)
6b.	Second Year Spanish	(1)
6c.	Third Year Spanish	(1)
6d.	Fourth Year Spanish	(1)
7a.	First Year Italian	(1)
7b.	Second Year Italian	(1)
7c.	Third Year Italian	(1)
8a.	Ancient History	(½–1)
8b.	Modern History	(½–1)
8c.	English History	(½–1)
8d.	American History, Civics	(½–1)
9a.	Elementary Algebra	(1)
9b.	Intermediate Algebra	(1)
9c.	Advanced Algebra	(½)
9d.	Plane Geometry	(1)
9e.	Solid Geometry	(½)
9f.	Plane Trigonometry	(½)
10.	Physics	(1)
11.	Chemistry	(1)
12.	Physical Geography	(½–1)
13.	Biology	(1)
14.	Botany	(½–1)
14a.	Zoology	(½–1)
15.	Bookkeeping	(½–1)
16.	Agriculture	(½–1)
17.	Drawing	(½–1)
18.	Manual Training	(½–1)
19.	Any high school subject or subjects not already used	(½–2)

WAYS OF OBTAINING ENTRANCE CREDIT

There are four ways in which credit for entrance subjects may be obtained. They are:

1. By passing the required Cornell University entrance examinations held in September in Ithaca and New York City, and in January (for applicants for the College of Engineering only) in Ithaca.

2. By passing the College Entrance Examination Board Examinations (the "Comprehensive" examinations are accepted excepting Mathematics Cp.H.) held in June in various places. Address the Secretary of the College Entrance Examination Board, 431 West 117th St., New York City.

3. By passing the Regents' examinations (for students who have prepared in New York State).

4. By presenting an acceptable school certificate.

RULES GOVERNING ADMISSION

Besides satisfying the entrance requirements, candidates for admission must comply with the following rules:

1. Every candidate for admission to an undergraduate course must deposit twenty-five dollars with the University. Candidates are warned not to send cash through the mails. A check, draft, or order should be payable to Cornell University and should be sent to the Office of Admissions, Cornell University. The deposit must be made not later than June 1 if the candidate is to be admitted in September to the College of Arts and Sciences or the College of Architecture, or the College of Home Economics, and not later than August 1 if he is to be admitted in September to any of the other colleges. It must be made not later than January 1 if the candidate is to be admitted in February to any of the colleges.

If the candidate matriculates, the deposit will be credited to his account, $10 for the matriculation fee, $1 for an examination-book fee, and $14 as a guaranty fund, which every undergraduate student is required to maintain and which is to be refunded upon his graduation or permanent withdrawal, less any indebtedness to the University.

If admission is denied a candidate, the deposit is refunded in full at any time.

A candidate may withdraw the application for admission, but a charge of $10 is regularly made for accrued expenses unless the application is withdrawn and a refund of the deposit in full is claimed before the due date, which is June 1 in the College of Arts and Sciences, the College of Architecture, and the College of Home Economics and August 1 in the other colleges. If an application is not withdrawn until after the due date of the college concerned, but is withdrawn before August 31, the $10 charged for accrued expenses is deducted and $15 of the deposit is refunded. No refund is made to an applicant who withdraws the application after August 31.

In the case of applications for admission in February, a withdrawal after January 1 incurs the regular charge of $10, and no refund is made for withdrawal after January 31.

The winner of a New York State Tuition Scholarship in Cornell University may apply for admission to the University and make the required deposit of $25 immediately after receiving formal notice of his appointment from the Commissioner of Education at Albany.

2. Every candidate for matriculation must submit to the Director of Admissions a satisfactory certificate of vaccination against smallpox, not later than August 1 if he is to be admitted in September, or not later than January 1 if he is to be admitted in February. It will be accepted as satisfactory only if it certifies that within the last five years a successful vaccination has been performed or three unsuccessful attempts at vaccination have been made.

3. Every candidate for admission to an undergraduate course must file with his application at the Office of Admissions either a certificate of good moral character or, if he has attended some other college or university without graduating from it, a certificate of honorable dismissal from it.

A NECESSARY PRECAUTION

Before coming to the University, the student should consult an occulist and have any defect of vision corrected. Unless he does so, he may begin his work under a disadvantage and run the risk of failure. The large amount of close work that is required in reading and drafting puts a strain on farsighted or otherwise imperfect eyes. Such a weakness, unless discovered and remedied before the student begins his work, may delay his progress and impair his health.

ADMISSION AT THE BEGINNING OF THE SECOND TERM

Certificates and credentials for admission at midyear should be in the hands of the Director of Admissions not later than January 15. Admission at midyear is possible only under the following conditions: (a) A student must meet the regular entrance requirements. (b) If a student enters as a freshman without advanced college credit the time required for his graduation may be more than four years, and may require attendance during one or more Summer Sessions at Cornell University. On application made to the Director of Admissions on or before January 15 in any year, special entrance examinations in any of the University entrance subjects may be arranged for students who must be examined in one or more subjects to complete their requirements for admission to the College of Engineering at midyear. These special entrance examinations are held in Ithaca on or about January 25 of each year.

ADMISSION TO THE COURSE IN ADMINISTRATIVE ENGINEERING

The requirements for admission to this course are the same as those for the regular Four-Year Course, page 38.

ADMISSION TO THE FIVE-YEAR COURSE IN MECHANICAL ENGINEERING

For admission to this course, the entrance requirements are those of the four-year course. The student completes the regular engineering work, spending more time on the advanced engineering work, and adding the equivalent of about one year of liberal arts work. A definite schedule for such a course has so far been laid down only by the Sibley School of Mechanical Engineering, (see p. 88).

ADMISSION TO THE FIVE-YEAR COURSE IN CHEMICAL ENGINEERING

The requirements for entrance to this course are those required for entrance to the B.Chem. course in the College of Arts and Sciences. Application should be made to that College.

ADMISSION TO THE SIX-YEAR COURSE

The six-year course, leading to the degrees of A.B. and C.E., or A.B. and M.E. or A.B. and E.E., requires admission to the College of Arts and Sciences, in which college the student is registered during the first four years. In order to make it possible to obtain the C.E., M.E., or E.E. degree at the end of the sixth year, the student must complete the freshman engineering subjects before the beginning of his fourth year, and must complete the list of sophomore subjects in Civil Engineering, Mechanical Engineering, or Electrical Engineering before the beginning of his fifth year. Advice and assistance in arranging such a course may be obtained by applying to the Director of the school concerned.

Owing to the large amount of liberal work in the curriculum of the School of Civil Engineering the two degrees of A.B. and C.E. may be obtained in five years plus two summer sessions.

ADMISSION FROM ANOTHER COLLEGE

A student who has attended another college may be admitted to advanced standing, provided he is in good standing in the college from which he comes and provided also that he meets the full entrance requirements of the College of Engineering. An applicant for admission in this way should file by mail with the Director of Admissions of Cornell University, on an official blank to be obtained from him, a formal application for admission stating definitely the branch of engineering desired, along with an official certificate, from the college or university already attended, of his honorable dismissal; his entrance credits in detail; his terms of attendance and the amount of work that he has completed; a detailed statement of the courses pursued; and the drawings and reports for which credit has been secured. He should also send a catalogue of the institution attended, writing on it his name and marking the entrance requirements that he has satisfied and each subject that he has completed.

SPECIAL ENTRANCE STUDENTS

The College of Engineering admits special entrance students, that is to say, applicants who have not fifteen acceptable units of entrance credit, only under exceptional circumstances. They must have had equivalent training satisfactory to the committee on admissions, and must be at least 21 years of age. After admission, such special students pursue the regular undergraduate courses, but will receive degrees only upon the completion of the regular entrance requirements.

ADMISSION AS A GRADUATE STUDENT

Graduates of this college or other colleges may enter the Graduate School of Cornell University and pursue work in the College of Engineering. Such a student may enter either as a candidate for a degree (M.C.E., M.M.E., M.E.E., M.S. in Engineering, or Ph.D.) or not, according to the character of his previous training. A prospective student should consult the Announcement of the Graduate School and apply to the Dean of the Graduate School. See also page 116.

UNDERGRADUATE TUITION AND OTHER FEES

Information about the amount and the manner of payments to be made by a student to the University should be looked for in the General Information Number. Fees for graduate students are given on page 118.

Tuition. The University charges undergraduate students registered in the College of Engineering tuition at the rate of four hundred dollars a year, payable $220 at the beginning of the first term and $180 at the beginning of the second term.

A student enrolled only for the second term of the academic year is required to pay tuition at the rate of the first term. The installment for any term becomes a liability at once when the student registers.

A Matriculation Fee of $10 and an examination book fee of $1 are required of every student upon entrance into the University; this fee must be paid at the time of registration. A new undergraduate student who has made the required deposit of $25 with the Treasurer need not make an additional payment of the matriculation fee, because the Treasurer will draw on the deposit for this fee.

A Laboratory Fee is required of all students registered in the College of Engineering, one-half of the fee at the beginning of each term, at the following rates: Freshmen in the College of Engineering, $25 a year; sophomores, juniors, and seniors in Mechanical Engineering and Electrical Engineering, $25 a year; sophomores, juniors, and seniors in Civil Engineering, $8 a year. Students taking a five-year course in the college pay this fee for only eight terms. Students in the College of Engineering who take laboratory courses in other colleges of the University are required to pay to the Treasurer a fee or deposit for materials used in the work. Students not registered in the College of Engineering but taking work in the shops are required to pay a laboratory fee at the rate of $3.50 a record hour. (A student who has taken, while in a non-engineering college of the University, part of the work required for an engineering degree shall, before receiving such technical degree, be required to pay to the University Treasurer such amount as would have been necessary if he had taken all such work while registered in the College of Engineering.)

A Health and Infirmary Fee of $6 a term is required at the beginning of each term, of every student. For a statement of the privileges given in return for this fee, see the General Information Number.

A Willard Straight Hall Membership Fee of $5 a term is required, at the beginning of each term of every student. Its payment entitles the student to share in the common privileges afforded by the operation of Willard Straight Hall, subject to regulations approved by the Board of Managers of the Hall. A fee of $5 a term is required of all graduate students except those who are members of the instructing staff, for whom membership is optional. The use of the hall is restricted to those who have paid this fee.

A Physical Recreation Fee is required at the beginning of each term of every undergraduate man and of every woman of the freshman and sophomore classes. It is $2 a term for men and $1 a term for women. Its payment entitles the student either to the use of the gymnasium and the University Playgrounds and to the use of a locker, with bathing facilities and towels, in the Gymnasium, the New York State Drill Hall, or the Schoellkopf Memorial Building, or else to the use of the women's gymnasium, recreation rooms, and playgrounds, and to the use of a locker if that is necessary.

A Graduation Fee is required, at least ten days before the degree is to be conferred, of every candidate for a degree. For a first or baccalaureate degree the fee is $10; for an advanced degree it is $20. The fee will be returned if the degree is not conferred.

Tuition and other fees become due when the student registers. The University allows twenty days of grace after the last registration day of each term. The last day of grace is generally printed on the registration coupon which the student is required to present at the Treasurer's office. Any student who fails to pay his tuition charges, other fees, and other indebtedness to the University, or who, if entitled to free tuition, fails to claim it at the Treasurer's office and to pay his fees and other indebtedness, within the prescribed period of grace, is hereby dropped from the University unless the Treasurer has granted him an extension of time to complete payment. For the conditions and terms of any such extension, see the General Information Number.

A tuition fee or other fee may be changed by the Trustees at any time without previous notice.

CHARGES FOR DELINQUENCIES

Every student is held responsible for any injury done by him to any of the University's property.

Assessments are levied upon the student in certain circumstances, under the following rules of the University:

A student desiring to be reinstated after being dropped from the University for delinquency in scholarship or in conduct shall first pay a fee of $25.

A matriculated student desiring to register after the close of registration day shall first pay a fee of $5. (Students in the Graduate School are excepted.)

A student desiring to file his registration of studies after the date set by his college for filing the same shall first pay a fee of $2.

A student desiring to take an examination or other test for the removal of a term condition (including the making up of a mark of "absent" or "incomplete") shall first pay a fee of $2 for each examination or other test.

A student desiring to make an appointment for the required medical examination or conference after twenty days from the last registration day of the term shall first pay a fee of $2.

For reasons satisfactory to the proper authority any of the above-mentioned assessments (except that levied for examination or other test to remove a condition) may be waived in any individual case if the student's failure to comply with the regulation was due to ill health or to other reasons beyond his control. Application for waiver should be made to the dean of the college enrolling the student, except in the case of the medical examination, in which case it should be made to the chairman of the Faculty Committee on Health.

COURSES OF STUDY IN THE COLLEGE

THE REGULAR FOUR-YEAR COURSES

Regular four-year courses are offered in the schools of the college, leading to the degrees of Civil Engineer, Mechanical Engineer, and Electrical Engineer. In addition these schools offer four-year courses leading to the degree of Bachelor of Science in Administrative Engineering.

The first year of all the courses is basically the same so that no student need make his choice of Civil Engineering, Mechanical Engineering, Electrical Engineering, or Administrative Engineering until near the end of the first year of residence. The curriculum of the first year is given on page 48 under the head of The Freshman Year.

The last three years of each regular four-year course are spent by the student under the direct supervision of one of the three schools. Further on in this Announcement there will be found, under the appropriate head, a particular statement of the curriculum of the last three years in each school.

In the last year of each course, certain options or electives are offered, so that each student may have a certain amount of freedom in placing the main emphasis of his work upon branches of the profession in which he may be most interested. These options and electives are clearly defined in the announcement of each school, on subsequent pages.

FIVE AND SIX-YEAR COURSES

As already mentioned on page 13 of this Announcement, arrangements may be made in each of the three schools of the College for a six-year course leading to the degree of A.B. and to either the C.E., M.E., or E.E. degree. In addition, the Sibley School of Mechanical Engineering offers a five-year course in Chemical Engineering in conjunction with the Department of Chemistry, and is prepared also to arrange a special five-year course leading to the degree of M.E. only. For details see the Announcements of the three schools in the pages following. Applications for any of these special arrangements should be made to the Director of the School concerned, except for the course leading to the degree of Chemical Engineer, for which application should be made to the Director of the Department of Chemistry.

MILITARY SCIENCE: PHYSICAL TRAINING

All men in the first two years of undergraduate courses must take in addition to the scholastic requirements for the degree, three hours a week in the Department of Military Science and Tactics. This

department is a unit of the Reserve Officers' Training Corps of the United States Army. For details of the work in the Department of Military Science and Tactics, see the General Information Number.

All women in the first two years of undergraduate courses, and all men of those two classes who are excused from military drill, must take, in addition to the scholastic requirements for the degree, three hours a week in the Department of Physical Training. For details of this work in the Department of Physical Training, see the General Information Number.

HYGIENE AND PREVENTIVE MEDICINE

All students are required, upon entering, to report to the Medical Adviser's Office of the University to make appointment for a physical examination.

Sophomores, A through M, also make their appointments for physical examination during the registration days of the first term. Sophomores, N through Z, juniors and seniors make their appointments for physical examination during the registration days of the second term.

All students in the first year of undergraduate courses are required to attend lectures on Hygiene and Preventive Medicine given once a week throughout the college year.

Required Courses

1. **Hygiene**. First term. Credit one hour. Required of all freshmen. One lecture-recitation each week, with preliminary examination and final. The use of a text-book will be required.

Students must report for registration and assignment to section, the men at the *Old Armory*, the women at *Sage Gymnasium*.

Sections for men: Assistant Professors Gould, Showacre, York, and Doctors Hawkins, Robinson, and Teagarden.

Sections for women: Assistant Professor Evans, Doctors Cuykendall and Stelle.

2. **Hygiene**. Second term. Credit one hour. Required of all freshmen. One lecture-recitation each week, with preliminary examination and final. The use of a text-book will be required.

Students must report for registration and assignment to section, the men at the *Old Armory*, the women at *Sage Gymnasium*.

Sections for men: Assistant Professors Gould, Showacre, York, and Doctors Hawkins, Robinson, and Teagarden.

Sections for women: Assistant Professor Evans, Doctors Cuykendall and Stelle.

Elective Courses

3. **Health Supervision of School Children**. Second term. Credit two hours. Assistant Professor Gould. T Th 12. Histology lecture room, *Stimson*. Registration at Hygiene Office, *Old Armory*.

A practical course of lectures and demonstrations designed to familiarize the student with the facts and methods necessary for making an effective health supervision of school children. Prerequisites suggested but not demanded: Human Physiology and Anatomy. Open to sophomores, juniors, and seniors.

4. **Advanced First Aid.** First and second term. Credit one hour. Assistant Professor SHOWACRE. First term: Anatomy lecture room, *Stimson*, F 9. Second term: S 9, Anatomy lecture room, *Stimson*. Registration at Hygiene Office, *Old Armory*. Prerequisites: Hygiene 1 and 2.

This course will include a discussion and practical demonstration of the main methods at hand for preventing accidents and for giving emergency treatment.

5. **Industrial Hygiene.** First term. Credit one hour. Assistant Professor GOULD. Th 12. Histology lecture room, *Stimson*. Registration at Hygiene Office, *Old Armory*. Prerequisites: Hygiene 1 and 2.

Factory sanitation, ventilation, and illumination; occupational poisoning and disease; factory legislation; accident prevention; fatigue in industry; preventive medicine in the industries.

6. **School Hygiene.** Professor YOUNG. See Physical Education 24.

7. **Rural Hygiene.** Second term. Credit one hour. Professor SMILEY. W 12. Anatomy lecture room, *Stimson*. Registration at Hygiene Office, *Old Armory*. Prerequisites: Hygiene 1 and 2. Not given in 1935 or 1936.

A general consideration of the health problems peculiar to rural areas with the presentation of practical schemes for the solution of these problems as far as possible.

8. **Mental Hygiene.** First term. Repeated in second term. Credit two hours. Section 1, Boardman A, M, F 11: Section 2, Histology lecture room, *Stimson*, W, F 2. Registration at Hygiene Office, *Old Armory*. Prerequisites: Hygiene 1 and 2. Doctors W. H. YORK and RUTH STELLE.

A study of the factors involved in the growth and maintenance of mental health: i. e., satisfactory human relationships, attitudes, and behavior. Discussion of the causes and mechanisms underlying the more common personality deviations.

THE REQUIREMENTS FOR GRADUATION

The degree of Civil Engineer, Mechanical Engineer, Electrical Engineer, or Bachelor of Science in Administrative Engineering, is conferred on candidates who have fulfilled the following requirements:

1. The candidate must have been in residence and registered in the College of Engineering for the last two terms and must have satisfied the University requirements in Military Training (or Physical Training), in Hygiene and Preventive Medicine, and in the payment of tuition and fees.

2. If admitted to the four-year course, he must have completed to the satisfaction of the Faculty of the College of Engineering all the subjects including elective hours, prescribed in the four-year curriculum as outlined by that faculty.

3. A student who transfers to the College of Engineering, after having spent one or more terms in another college of Cornell University or elsewhere, must conform to the requirements for graduation that would have applied if he had been registered in this college from the time he matriculated in the University.

TWO DEGREES IN ONE YEAR. In case a person has satisfied the requirements for any baccalaureate degree, he shall not be recommended for any other baccalaureate degree until he shall have completed at least one year of further residence and of work acceptable to the Faculty on whose recommendation the second baccalaureate degree is to be conferred.

THE FRESHMAN YEAR

THE SCHEDULE OF STUDIES

There is fundamentally a single schedule of studies for all students in the freshman year of the College of Engineering. The prescribed schedule is as follows: the numbers of the courses refer to the lists of courses printed on the next two pages. Certain courses are for all freshmen, while others are for freshmen in the school indicated whether enrolled in the regular course, or in Administrative Engineering, in that school.

	Hours	
	1st Term	*2nd Term*
Analytical Geometry and Calculus 5a, 5b	5	5
Physics 11, 12	4	4
Chemistry 106a, b	3	3
Drawing 200, 201 (C.E.)	3	3
Descriptive Geometry and Drawing 120, 121 (M.E., E.E.)	3	3
Elementary Surveying 110 (C.E.)	3 or 0	0 or 3
Elementary Surveying 111 (M.E., E.E.)	2 or 0	0 or 2
Woodwork 102 (M.E., E.E.)	0 or 1	1 or 0
Introductory Engineering Laboratory 103	0 or 1	1 or 0
Introductory Lectures 130	1	0
Hygiene 1, 2	1	1
Total number of hours each term (C.E.)	20 or 18	17 or 19
Total number of hours each term (M.E., E.E.)	19	18

In addition to taking the courses named in the above schedule, all freshmen must satisfy the University's requirement of three actual hours a week throughout the year in Military Science and Tactics (or in Physical Training; see the General Information Number).

For the schedules of the sophomore, junior, and senior years in Civil Engineering, Mechanical Engineering, Electrical Engineering, or Administrative Engineering, consult the announcement of the appropriate school in following pages.

THE COURSES OF INSTRUCTION, FRESHMAN YEAR

The following courses of instruction are those prescribed for all students in the freshman year of the four-year course leading to the degree of Civil Engineer, Mechanical Engineer, Electrical Engineer, or Bachelor of Science in Administrative Engineering. The courses in Mathematics, Physics, and Chemistry are given in the College of Arts and Sciences; the other courses in the list are given in the College of Engineering.

MATHEMATICS

5a. **Analytical Geometry and Calculus.** First term. Credit five hours. Repeated in second term.

5b. **Analytical Geometry and Calculus.** Second term. Credit five hours. Given also in first term.

Course 5a or 5b may not without special permission, be taken simultaneously with any of the other courses in Mathematics. Courses prerequisite to 5a or 5b are Solid Geometry and Trigonometry.

PHYSICS

11. **General Physics.** Required of Freshman Engineering Students. First term. Credit four hours. Prerequisite Mathematics 1 and 3 or the equivalent. Entrance physics is desirable but not required.

Two lectures, two recitations and one laboratory period a week as assigned, covering the subjects of mechanics, wave motion, sound and light.

Rockefeller Hall. Assistant Professor GRANTHAM and instructors.

12. **General Physics.** Required of Freshman Engineering students. Second term. Credit four hours. Prerequisite Mathematics 1 and 3 or the equivalent. It is recommended, though not required, that Physics 11 precede this course.

Two lectures, two recitations and one laboratory period a week as assigned, covering the subjects of electricity and heat.

Rockefeller Hall. Assistant Professor GRANTHAM and instructors.

CHEMISTRY

Entrance credit in chemistry does not carry with it University credit in Courses 106a or 106b. If a student entering the University from a preparatory school desires credit for these Courses, he must pass an examination set by the Department of Chemistry. This examination is held in Ithaca on the same day in September as the entrance examination. University credit in Courses 106a and 106b that is obtained by passing this examination does not carry with it entrance credit in Chemistry.

106a. **General Chemistry.** First term. Credit three hours.

One lecture, one recitation, and one laboratory a week as assigned.

Baker Laboratory. Assistant Professor LAUBENGAYER, Mr. FERGUSON, and assistants.

106b. **General Chemistry.** Second term. Credit three hours. Prerequisite Chemistry 106a.

One lecture, one recitation, and one laboratory a week as assigned.

Baker Laboratory. Assistant Professor LAUBENGAYER, MR. FERGUSON, and assistants.

DRAWING, SURVEYING, SHOPWORK, INTRODUCTORY LABORATORY AND INTRODUCTORY LECTURES

120. **Descriptive Geometry** (M.E. and E.E. students). First term. Prerequisite to course 121. One recitation and 2 two and one-half hour drawing periods a week. Instruction and drill in the use of drawing room equipment, lettering and the following essentials of descriptive geometry: the description of points, lines, planes and solids; the description of in-space relations of points, lines, planes and solids, including intersections and tangents; the graphic computation of linear and angular measurements; the development of surfaces. Professor TOWNSEND and Instructors. *East Sibley.*

121. **Mechanical Working Drawing** (M.E. and E.E. students). Second term. Prerequisite course 120. One recitation and 2 two and one-half hour drawing periods a week. This course includes: the purposes of working drawings; the principles of planning drawings to meet their purposes; execution of planning sketches, drawings, tracings, bills of material, drawing lists, etc. Professor TOWNSEND and Instructors. *East Sibley.*

200. **Drawing** (C.E. students). First term. Credit three hours. Use of instruments, free-hand lettering, titles, geometrical problems, simple projections, tracing. Professor PARSON and Assistant Professor PERRY.

201. **Drawing** (C.E. students). Second term. Credit three hours. Projections and intersections of solids, practical problems, orthographic projection with sections, use of different scales, scale drawings, conventional signs, isometric drawing, line shading, topographic signs for mapping. Professor PARSON and Assistant Professor PERRY.

110. **Elementary Surveying.** Freshmen. (Primarily for C.E. students). Either term as assigned. Credit three hours. Use of steel tape, level and transit; fundamental surveying methods; measurement of lines, angles, and differences of elevation; land surveying, areas and plotting. Recitations, field work, computations, and mapping. Text-book: Breed and Hosmer's *Elementary Surveying.* First Term, one recitation and two field or computation periods a week; Second Term, three recitations a week for the first six weeks and three field or computation periods a week for the remainder of the term. Professor UNDERWOOD and Assistant Professor LAWRENCE. *Lincoln Hall.*

111. **Elementary Surveying** (M.E. and E.E. students.) Freshmen. Either term as assigned. Credit two hours. Use of steel tape, level and transit; fundamental surveying methods, measurement of lines, angles and differences of elevations; land surveying. Recitations, field work and computations. Textbook: Breed and Hosmer's Elementary Surveying. First term: two recitations or two field or computation periods a week. Second term: two recitations a week during the first half of the term, and two field or computation periods a week during the remainder of the term. Professor UNDERWOOD and Assistant Professor LAWRENCE, Messrs. SPRY and BOYLES. *Lincoln Hall.*

102. **Woodshop.** Freshmen. One hour either term as assigned. Wood working; the use of hand and machine tools for wood working followed by instruction in pattern making, construction of core boxes, etc.; demonstration of form turning. Messrs. BUSH and YAWGER. *Rand Hall, Third floor.*

103. **Introductory Engineering Laboratory.** Freshmen. One hour either term as assigned. Elementary laboratory work and study of the various materials, processes and machines commonly used in engineering work. Demonstrations, followed usually by practice in forging, welding, hardening, and tempering, drop forging, metallizing and brazing, oxy-acetylene cutting and welding, atomic hydrogen, and electric welding. Also study of pipe and pipe fittings, soil pipe and fittings, threaded fastenings, bearings, instruments of measurement, steam engine, gasoline engine, electric motors and steam pump. Assistant Professor MORDOFF and Messrs. HODGES and HEAD.

130. **Introductory Lectures.** Freshmen. Credit one hour. One lecture a week. This course of lectures is designed to introduce the first-year men to the various fields of engineering, and to demonstrate to them some of the simpler and more general methods of engineering construction. It is the purpose of the lectures to awaken the interest of the freshmen in their chosen profession through the aid of vivid description, of stimulating biography, and of personal experience. *Lecture room to be assigned in the fall.*

SCHOOL OF CIVIL ENGINEERING

OUTLINE OF THE INSTRUCTION

The object of the instruction is to impart knowledge of fundamental principles of the design and behavior of structures and works met in Civil Engineering. Emphasis is placed upon engineering as an applied science rather than as a vocational technique.

The instruction in Mathematics, Chemistry, Physics, Geology, Economics, Psychology, English, and the languages is given in the College of Arts and Sciences; and all other regular subjects in the course are of an engineering nature and are given in the School of Civil Engineering, or in the Schools of Mechanical Engineering or Electrical Engineering.

The following is a brief outline of the scope and purposes of instruction in various departments of the School of Civil Engineering:

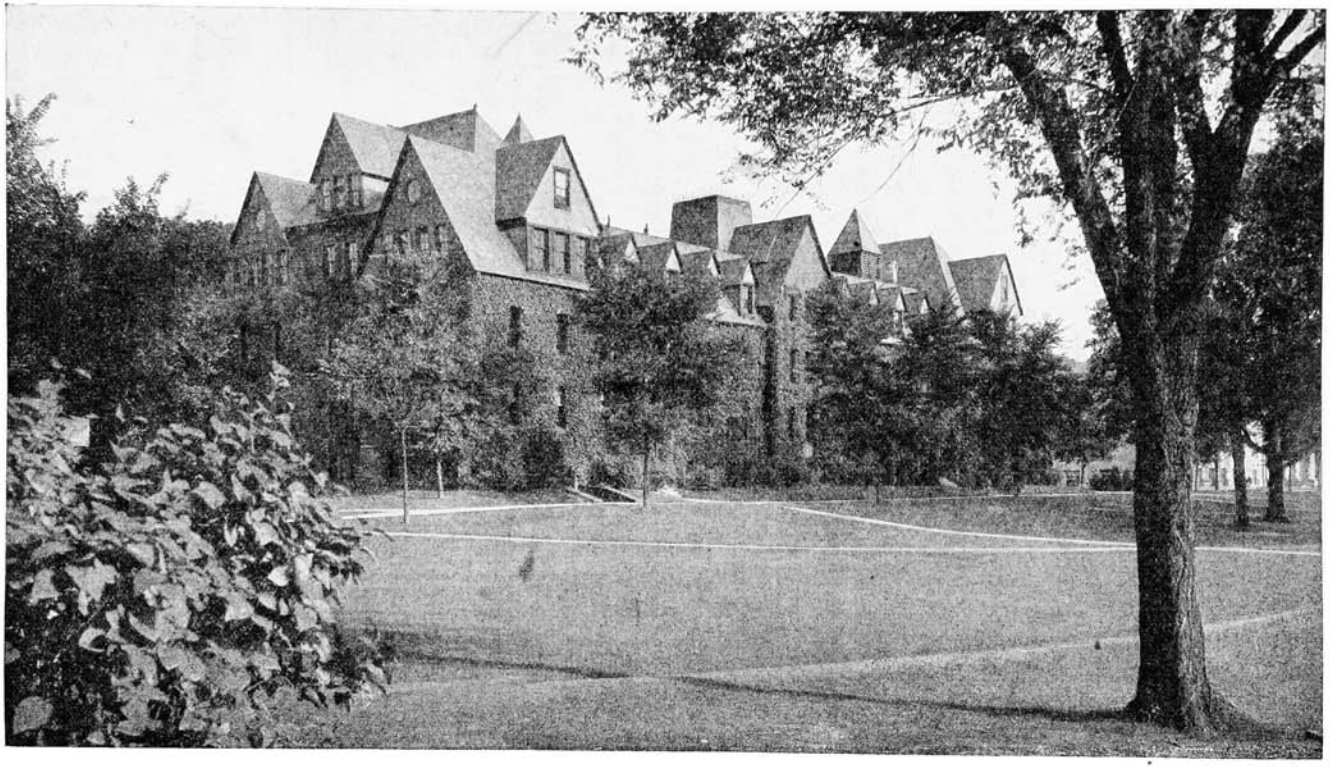
1. Surveying

An important branch of Civil Engineering is the making of surveys for the accurate location of properties, for the purpose of mapping, and for the control of engineering works. Instruction is given in this department in the use of surveying instruments, in precise leveling and measuring, and in making topographic, hydrographic, subterranean and geodetic surveys. The student is taught the elements of field astronomy, and makes astronomical observations in relation to survey control. Instruction is given in the principles and present practices in photographic and aerial surveying.

An important feature of instruction in this department is the work done by all students in the School at the Summer Survey Camp near Cayuta Lake, New York. Field practice is here given in triangulation and precise leveling and their control. Railroad and highway location surveying is also conducted by the students. They become familiar with field organization, and hold the various positions in field and office parties.

2. Mechanics of Materials

In this department classroom and laboratory instruction is given to the student in the principles of mechanics as the fundamental basis for the design of engineering structures and works. An important feature of instruction in this department is the work done by the student in the laboratory, where he obtains experience in dynamical actions and in the behavior of structural members under load. Demonstration and verification of the behaviors studied in the classroom are here developed.



LINCOLN HALL
The Main Building of the School of Civil Engineering

Opportunity is afforded the advanced student in mechanics for analytical and experimental work in the theory of elasticity, in photoelasticity, in the application of analogies and the use of models as they apply to engineering analysis and design.

3. Materials of Construction

The purpose of the work in this department is to acquaint the student with the processes of manufacture of the materials of construction, and the properties of these materials which are important in their behavior in engineering structures. In the laboratory the student is afforded opportunity for experience in the actual behavior of materials under load and other service conditions. It is not the purpose of this instruction to develop laboratory technicians, but rather to provide the student with physical experience and concepts of the behavior of materials of engineering.

4. Hydraulic Engineering

The work in this department begins with the fundamental behavior of fluids and continues into the design and operation of hydraulic works. In the Hydraulic Laboratory the student is instructed in the principles of hydraulic flow and measurement. The advanced student is afforded opportunity for study in hydrodynamics, experimental study in channel flow, pipe lines, weirs, spillways, and other hydraulic units.

In Water Power Engineering the student is given instruction in the methods of developing hydraulic power, the principles underlying the design and use of hydraulic machines, and in hydroelectric development.

Instruction is given to the student in the development of public water supplies and the principles of water purification. Instruction is also afforded the student in reclamation, canalization, and river and harbor development.

5. Municipal and Sanitary Engineering

The object of the instruction in this department is to provide the student with the principles underlying sewer systems, the treatment of sewage, water supply and distribution, purification of water and the operation of sanitary works. Fundamental instruction in classroom and laboratory is given in sanitary biology underlying the biological processes utilized in the purification of water and the treatment of sewage.

6. Transportation Engineering

The work in this department relates to the location, construction, operation, maintenance, and economics of various agencies of transportation. Instruction begins in the economic location and construc-

tion of railways and highways. It continues with study covering maintenance-of-way and the operation and management of railroads and highways.

A feature of the work in highway engineering is the laboratory instruction giving students experience in the study and testing of soils of highway subgrades, and in the testing of materials used in road construction.

7. Structural Engineering

In this department the student receives instruction in the design of bridges, buildings, and other structures of timber, masonry, concrete, steel, and other materials. Instruction is also offered in more advanced forms of bridge and building design and in the principles underlying their analysis. The student is also given instruction in the principles and methods involved in foundation work for bridges, buildings, and other land and waterfront structures.

8. Regional and City Planning

Instruction in Regional Planning is given by the Colleges of Engineering and Architecture in cooperation. The work does not recognize Regional or Town Planning as a separate profession, and hence no attempt is made to give the student technical proficiency in planning, nor even any large array of factual information. The courses deal in a broad way with the adaptation of man's environment to suit his needs and desires. A study is made of past and possible future achievement in the field of planned and controlled developments of public and private properties as the necessary basis for better living.

Emphasis is placed on the fact that historically and logically, the problems presented by large scale planning are so difficult that no one professional group is competent to comprehend them, much less to solve them. It is shown that actual achievement must finally rest on the united efforts of groups composed of people of diverse interests and widely varying training. The courses offered are therefore open to upper classmen and graduates in all colleges of the University.

9. Administrative Engineering in the School of Civil Engineering

The large number of Civil Engineering graduates who hold executive administrative positions is evidence of the usefulness of such a training for these positions. Engineering methods are finding increased application in problems of executive management. This is due in part to the increasing scientific development underlying the operation of works and processes, and in part to the nature of the training of the engineer in fact gathering and analytical study.

In order to strengthen the instruction in the economic, financial, legal, and functional aspects of business without at the same time sacrificing the fundamental instruction of civil engineering in its various branches, the School of Civil Engineering offers a four-year course in Administrative Engineering leading to the degree of B.S. in Administrative Engineering.

The opportunities in the field of administration for one trained as a civil engineer have been rapidly increasing in recent years. Railroad and public utility operation and management, highway administration, the broad field of construction, the operation and maintenance of public works, transit systems, river and harbor facilities, power developments, reclamation and conservation works, city and regional planning, and city management, offer large and rapidly growing fields of administrative service for the civil engineer.

OPPORTUNITIES FOR PROFESSIONAL DEVELOPMENT

During the year non-resident lecturers are heard by the students on technical and professional subjects. The Ithaca Section of the American Society of Civil Engineers meets frequently and the students have an opportunity to participate in these meetings. There is also a Student Chapter of the American Society of Civil Engineers operated by the students themselves. The *Cornell Civil Engineer*, a technical journal appearing monthly through the school year, is managed and edited by students in the School.

COURSES LEADING TO THE DEGREE OF CIVIL ENGINEER

1. The Regular Four-Year Course

THE FRESHMAN YEAR

The schedule of studies prescribed for all students in the freshman year of the College of Engineering, is set forth in full under the head The Freshman Year, beginning on page 48.

THE SOPHOMORE YEAR

	Hours 1st Term	Hours 2nd Term
Public Speaking 1	3 or 0	0 or 3
Engineering Geology 501	0 or 3	3 or 0
Field Astronomy 182	0	2
Drawing 202	1	0
Drawing 203	0	1
Descriptive Geometry 205	2	0
Descriptive Geometry 206	0	2
Surveying 211	2	0
Surveying 212	0	2
Mechanics 220	5	0
Mechanics Laboratory 220A	2	0
Mechanics 221	0	4
Mechanics Laboratory 221A	0	1
Engineering Construction 264	3 or 0	0 or 3
Technical Writing 294	0 or 3	3 or 0
Total number of hours each term	18	18

Summer Survey 213 (four weeks in summer vacation)	4
Location Surveying 260A (one week in summer vacation)	1

In addition to these courses, sophomores are required to take Military Drill.

THE JUNIOR YEAR

Introduction to Economics 3	3 or 0	0 or 3
Materials 225	0 or 3	3 or 0
Materials Laboratory 226	0 or 3	3 or 0
Hydraulics 240	4	0
Municipal Sanitation 252	0	4
Route Surveying and Drawing 260B	3 or 0	0 or 3
Stress Analysis and Structural Design 270	4	0
Structural Design 271	0	3
Concrete Construction 280	0 or 3	3 or 0
Foundations 281	3 or 0	0 or 3
Total number of hours each term	17	16

Students, desiring to specialize in a field requiring it, may, subject to the approval of their class adviser, defer certain courses of the junior year not fundamental or prerequisite to the senior work until the senior year in order to take elective or required courses of the senior year in the junior year. A student may not, however, anticipate the work of the curriculum by more than one year.

THE SENIOR YEAR

Heat-Power Engineering 3P43	3 or 0	0 or 3
Essentials of Electrical Engineering 417	0 or 4	4 or 0
Engineering Problems 223	0 or 2	2 or 0
Water Supply 230	0 or 3	3 or 0
Highway Engineering 265	3 or 0	0 or 3
Engineering Law 290	3 or 0	0 or 3
Engineering Management 293	0 or 3	3 or 0
Elective*	9 or 6	6 or 9
Total number of hours each term	18	18

*Of the elective hours, at least six must be taken in the School of Civil Engineering. The elective courses taken outside the School of Civil Engineering must be selected from among those not open to freshmen, unless the course selected has the special approval of the class adviser.

Not more than four hours credit in Advanced Military Science and Tactics will be accepted toward meeting the requirements for the C.E. degree.

Administrative Option

To meet the needs of those students who while primarily interested in Civil Engineering, still wish to get a more thorough training in Business Management and Administrative Engineering courses, the following option leading to the degree of Civil Engineer is offered:

SOPHOMORE YEAR

	Hours	
	1st Term	*2nd Term*
Public Speaking 1	3 or 0	0 or 3
Economics 3	0 or 3	3 or 0
Field Astronomy 182	0	2
Drawing 202	1	0
Drawing 203	0	1
Descriptive Geometry 205	2	0
Descriptive Geometry 206	0	2
Surveying 211	2	0
Surveying 212	0	2
Mechanics 220	5	0
Mechanics Laboratory 220A	2	0
Mechanics 221	0	4
Mechanics Laboratory 221A	0	1
Engineering Construction 264	3 or 0	0 or 3
Technical Writing 294	0 or 3	3 or 0
Total number of hours each term	18	18
Summer Survey 213 (four weeks in summer vacation)		4
Location Surveying 260A (one week in summer vacation)		1

In addition to these courses, sophomores are required to take Military Drill.

JUNIOR YEAR

Elementary Accounting	3	0
Corporation Finance	0	3
Materials 225	3 or 0	0 or 3
Materials Lab. 226	3 or 0	0 or 3
Concrete 280	0 or 3	3 or 0
Route Surveying 260B	0 or 3	3 or 0
Stress Analysis and Structural Design 270	4	0
Structural Design 271	0	3
Hydraulics 240	0	4
Geology 501	3	0
Total number of hours each term	16	16

SENIOR YEAR

Money or Banking	0 or 3	3 or 0
Cost Accounting	0 or 3	3 or 0
Engineering Law 290	3 or 0	0 or 3
Municipal Sanitation 252	4	0
Engineering Problems 223	2 or 0	0 or 2
Water Supply 230	3 or 0	0 or 3
Highways 265	0 or 3	3 or 0
Heat Power 3P43	0 or 3	3 or 0
Electrical Engineering 417	4 or 0	0 or 4
Foundations 281	0	3
Electives	3	3
Total number of hours each term	19	18

Any of the following courses may be taken profitably as an elective: Industrial Combinations, Ec. 32; Public Utilities, Ec. 33; Transportation, Ec. 34; Engineering Management, C.E. 293A; Valuation Engineering, C.E. 295; Municipal Government, C.E. 256.

2. A Six-Year Course Leading to the Degrees of A.B. and C.E.

The requirements for admission to this course are those of the College of Arts and Sciences, in which the student is registered for the first four years. The student must complete the freshman engineering subjects before beginning his fourth year, and he must complete the sophomore subjects in Civil Engineering before beginning his fifth year. By attending two Summer Sessions, this combined course may be completed in five years. Advice and assistance in arranging the six-year course may be obtained by applying to the Director of the School of Civil Engineering.

3. A Four-Year Course in Administrative Engineering Leading to the Degree of B.S. in A.E. With Special Reference to Civil Engineering

The requirements for admission to this Course are the same as for the regular four-year C.E. Course, see page 38.

THE FRESHMAN YEAR

There is fundamentally a single schedule of studies prescribed for all students in the freshman year of the College of Engineering. That schedule is set forth in full under the head The Freshman Year, beginning on page 48.

THE SOPHOMORE YEAR

	Hours 1st Term	Hours 2nd Term
Economics 3....	3	0
Labor Relations...	0	3
Elementary Accounting 3A31....	0	3
Business and Industrial Management 3A23.	0	4
Mechanics 220....	5	0
Mechanics 221....	0	4
Engineering Construction 264.	3	0
Technical Writing 294.	3	0
Engineering Geology 501. ..	0	3
Adv. Surveying 211A...	2	0
Adv. Surveying, including Astronomy, 212A. ...	0	2
Drawing and Intersections 208. ...	3	0
Total number of hours each term.. ...	19	19
Summer Survey 213 (four weeks in summer vacation). .		4
Location Surveying 260A (one week in summer vacation). .		1

In addition to these courses, sophomores are required to take Military Drill.

THE JUNIOR YEAR

	Hours 1st Term	Hours 2nd Term
Economics 11, Money and Banking. ...	3	0
Public Speaking 1.... ..	3 or 0	0 or 3
Economics 31, Corporation Finance... ..	0 or 3	3 or 0
Business Statistics....	0	3
Psychology 16...	0	3
Materials 225..... .	3	0
Materials Laboratory 226A. ..	2	0
Hydraulics 240A..... ..	0	3
Route Surveying and Drawing 260C. ..	2	0
Structural Analysis 270A.. ..	2	0
Structural Design 271... ...	0	3
Concrete Construction 280.	3	0
Foundations 281A...	0	2
Total number of hours each term.. ..	18	17

THE SENIOR YEAR

	Hours 1st Term	Hours 2nd Term
Engineering Law 290.	3	0
Adv. Engineering Law 290A. ..	0	3
Engineering Management 293A.	3	0
Valuation Engineering 295.	0	3
Cost Accounting 293B.	0	3
Engineering Problems 223. ..	2	0
Municipal Sanitation 252A.	3	0
Water Supply 230A.	0	3
Transportation 269..	3	0
Power and Prime Movers.	0	3
Electives..	4	3
Total number of hours each term. ...	18	18

It is possible so to arrange the work of a five-year course that the C.E. degree may be obtained at the end of the first four years and the B.S. in A.E. degree at the end of the fifth year. Declaration of intention to take the five-year C.E.-A.E. curriculum should be made at the beginning of the second year.

LIST OF THE COURSES OF INSTRUCTION

The courses in the following list are designed for sophomores, juniors, and seniors. Those courses which are designed for freshmen are described under the head THE FRESHMAN YEAR, page 48. The following courses in Geology, Economics, Psychology, and Public Speaking are given in the College of Arts and Sciences.

GEOLOGY

501. **Engineering Geology.** Required of Sophomores in Civil Engineering. Either term as assigned. Credit three hours. Registration by special permission. Lectures and laboratory work. The practical application of geologic principles and the occurrence of such economic materials as are of importance to engineering students, the whole subject being treated with reference to their needs. *McGraw Hall.* Professor RIES.

ECONOMICS

3. **Introduction to Economics.** Repeated in second term. Credit three hours, A survey of the existing economic order, its more salient and basic characteristics. and its operation. Assistant Professor O'LEARY.

11. **Money and Banking.** Repeated in second term. Credit three hours. Prerequisite, Economics 1 or its equivalent. Professor Reed. Goldwin Smith C. A study of the history and the theory of money and banking.

31. **Corporation Finance.** First term. Credit three hours. Prerequisite, 3A31. Assistant Professor O'LEARY. *Goldwin Smith* 142.
A study of the financial problems of the business corporation from the points of view of the management, of the investor, and of the public.

PSYCHOLOGY

16. **Applications of Psychology.** Second term. Credit three hours. Assistant Professor JENKINS. *Goldwin Smith* A.
A critical review of the attempts to apply psychological facts and methods to the solution of technological problems.

PUBLIC SPEAKING

1. **Public Speaking.** Either term. Credit three hours. *Goldwin Smith* 24. Designed to give the student the fundamentals of speech preparation and to help him acquire a simple, direct manner of speaking. Original speeches and interpretation of selections. Professor DRUMMOND.

MECHANICAL ENGINEERING

3P43. **Heat-Power Engineering.** Required of all seniors in Civil Engineering. For a description of this course see page 98 of this Announcement.

ELECTRICAL ENGINEERING

417. **Essentials of Electrical Engineering.** Either term. Required of all seniors in Civil Engineering. For description of this course see page 111 of this Announcement.

ASTRONOMY

182. **The Elements of Field Astronomy.** Either term. Credit two hours. Prerequisites, Astronomy 180, and Mathematics 3 or Surveying 110. Required of students in Civil Engineering. For hours and rooms see Schedule of Courses, Sections and Rooms for School of Civil Engineering. Professor BOOTHROYD and Mr. PENDLETON.

186. **Geodetic Astronomy.** Throughout the year. Credit three hours. Prerequisites, Astronomy 182, Astronomy 181, or Advanced Surveying 212 and Mathematics 4a and 4b or equivalents. This course is given in alternate years. Professor BOOTHROYD.

DESCRIPTIVE GEOMETRY AND DRAWING

200 and 201. **Drawing.** Freshmen. Credit three hours each term. See page 49.

202. **Drawing.** Sophomores. First term. Credit one hour. Lettering—Roman, gothic and other styles of letters, with practice in forming the letters and combining them into appropriate titles; projections and intersections of practical problems. Professor PARSON.

203. **Drawing.** Sophomores. Second term. Credit one hour. Projections and intersections using practical problems, practice with water colors in the rendering of flat and curved surfaces, and in the use of crayon, rendering in sepia, stone and concrete bridges. Professor PARSON.

204. **Advanced Drawing.** Elective. Juniors and seniors. Second term. Credit three hours. Perspective drawings, rendered in pencil, ink, and washes, of architectural buildings (exterior and interior), concrete bridges, dams, and other engineering works; building details of window frames, doors, cornices, molding, stairs, and other simple details, to give the student some insight into detailing parts of plans, and to familiarize him with reading working drawings; engineering drawings, rendered in crayon and color, to enable the student to supplement ordinary working drawings with artistic representations so portrayed as to be readily intelligible to non-technical committees, etc. Professor PARSON.

205. **Descriptive Geometry.** Sophomores. First term. Credit two hours. A study of the representation of lines, planes, surfaces, and solids, with practical applications. Two two-hour exercises each week. Assistant Professor POND.

206. **Descriptive Geometry.** Sophomores. Second term. Credit two hours. A continuation of Course 201. A study of surfaces and solids; tangencies, intersections, and developments; warped surfaces; perspective. When feasible practical problems are introduced throughout the course. Two two-hour exercises each week. Assistant Professor POND.

207. **Advanced Descriptive Geometry.** Elective. Juniors and seniors. Either term. Credit three hours. A continuation of courses 201 and 202. Problems in intersections, developments, warped surfaces, shade, shadows, and perspective. A considerable portion of the time is devoted to stereotomy, with practical problems in stone cutting and the making of accurate templet drawings. Assistant Professor POND.

208. **Drawing and Intersections.** Graphical representations of point, lines, planes, and their interrelations. Practical applications in buildings, stone work, sheet iron work. Professor PARSON.

SURVEYING

110. **Elementary Surveying.** Freshmen. Either term. Credit three hours. See page 50.

211. **Advanced Surveying.** Sophomores. First term. Credit two hours. Prerequisite course 110. City, topographic, and mine surveying; surveys of the

United States Public Lands; precise measurements; subterranean surveys; city planning; earth volumes. Professor UNDERWOOD, Assistant Professor LAWRENCE and Mr. PENDLETON.

211-A. **Advanced Surveying.** Primarily for students in Administrative Engineering. Sophomores. First term. Credit two hours. Prerequisite Course 110. City, topographic, and mine surveying; surveys of the United States Public Lands; precise measurements, subterranean surveys; city planning; earth volumes. Professor UNDERWOOD and Assistant Professor LAWRENCE.

212. **Advanced Surveying.** Sophomores. Second term. Credit two hours. Prerequisite course 211. Topographic, hydrographic, and geodetic surveying; transit and stadia; plane table; sextant; soundings; triangulation; base lines; precise leveling. Recitations, and field and office work. Textbook: Breed and Hosmer's *Higher Surveying*. Professor UNDERWOOD, Assistant Professor LAWRENCE, and Mr. PENDLETON.

212-A. **Advanced Surveying.** Primarily for students in Administrative Engineering. Second term. Credit two hours. Prerequisite Course 211. Topographic, hydrographic and geodetic surveying; transit and stadia; plane table; sextant; soundings; the elements of field astronomy; geodetic surveying, including triangulation, base line measurements and precise leveling, briefly considered. Recitations, and field and office work. Textbook: Breed and Hosmer's *Higher Surveying*. Professor UNDERWOOD and Assistant Professor LAWRENCE.

213. **Summer Survey: Topographic, Hydrographic, and Geodetic Survey; Camp.** Sophomores. (Attendance for five weeks is required for 213 and 260-A, four weeks for 213 and one week for 260-A.) Credit four hours. Date of beginning to be announced in second term. Prerequisite course 212. Practical experience in surveying under field conditions. An extensive topographic survey with the transit and stadia and the plane table, and a hydrographic survey of a portion of Cayuta Lake are executed, and field maps are made. Triangulation and precise leveling control the topographic and hydrographic work. A base line is measured with invar tapes. Solar observations for azimuth and time are made and results computed. Each student takes part in all branches of the work. Field and office work six days a week. Professors UNDERWOOD and BOOTHROYD, Assistant Professors LAWRENCE, PERRY, THATCHER, and Mr. SPRY.

214. **Mapping.** Elective. Upperclassmen. Required of students in Forestry. Second term. Credit two hours. The construction of a final topographic map of the area covered by the field work of Course 213 during the preceding summer. The field sheets are combined for this purpose, reduced in scale from 1:4800 to 1:12000, and reproduced, using the triangulation system as a base for the work. Lectures and drawing. Professor UNDERWOOD.

215. **Problems in the Adjustment of Observations.** Elective. Upperclassmen. Second term. Credit one hour. Prerequisite course 213. A series of examples in the adjustment of typical surveying work such as leveling, direct measurement of lines and angles, and simple triangulation figures, using the method of least squares. Lectures and problems. Textbook: Leland's *Notes on the Adjustment of Observations*. Professor UNDERWOOD.

216. **Least Squares: Adjustment of Observations.** Elective. Second term. Credit two hours. Prerequisites, Calculus and Physics. Lectures and recitations. The course is designed for students who have experimental investigations in view. Applications are made to problems in physics, astronomy, mechanics, hydraulics, surveying, etc., with some attention given to the derivation of empirical formulae. Two hours a week, as may be arranged. Professor UNDERWOOD.

217. **Advanced Topographic Surveying.** Elective. Upperclassmen. Second term. Credit two hours. Prerequisite course 213. Economics of surveying methods. Surveys for special purposes such as extensive construction work; storage and distribution of water for irrigation; earthwork on a large scale; lines of communication; topographic reconnaissance, etc.; photographic surveying.

Lectures, recitations, and assigned readings. Two hours a week. Professor UNDERWOOD.

218. **Geodesy and Geodetic Laboratory.** Elective. Upperclassmen. First term. Credit three hours. Prerequisite courses 182 and 212. A course for the consideration of special problems in geodetic work. Precise leveling; deflection of the plumb line; figure of the earth; use and investigation of geodetic instruments and apparatus such as circles, levels, micrometer microscopes, standards of length, thermometers, pendulums, magnetic apparatus, etc. Subject to arrangement to meet the special needs of students. Lectures, reading, discussions, and laboratory work. Three periods a week. Professor BOOTHROYD.

219. **Photographic and Aerial Surveying.** Elective. Upperclassmen. Second term. Credit three hours. Prerequisite, Advanced Surveying, Course 212 or Course 211-A. The principles of photographic surveying; surveys with camera stations on the ground, including stereoscopic methods; aerial surveys and the making of maps from such surveys; ground control. Recitations, lectures, and collateral reading. Three hours a week. Professor UNDERWOOD.

MECHANICS OF ENGINEERING

220. **Mechanics of Engineering.** Sophomores. First term. Credit five hours. Repeated in one section, second term. Prerequisite course, Mathematics 5b. (See Course 220-A below.) Statics of a material point and of rigid bodies and structures by algebraic and by graphic methods of analysis; chains and cords; centers of gravity; movements of inertia; kinetics and dynamics of a material particle; centrifugal and centripetal forces; dynamics of collections of material particles forming rigid bodies; pendulums; friction, work, power, measurement of power; the general theorem of work and energy applied to collections of rigid members forming machines; impact, impulse and momentum. Five recitations a week. Emphasis is placed upon the theory as well as upon the use of consistent units and correct numerical work. Facility in the use of the slide rule is essential. Professors GEORGE and RETTGER and Assistant Professor HOWELL.

220-A. **Mechanics Laboratory.** Sophomores. First term. Credit two hours. One two and one-half hour period in the laboratory together with a write-up period of equal length outside. Courses 220 and 220-A are closely correlated and must be taken concurrently. This course consists of experiments (both qualitative and quantitative) designed to illustrate the principles of mechanics covered in Course 220. In general, the experiments are performed by the students themselves, and a complete, well-arranged report on each experiment is required of each student. Instruction in the use of the slide-rule and of the planimeter is included in the work. Professors GEORGE and RETTGER and Assistant Professor HOWELL.

221. **Mechanics of Engineering.** Sophomores. Second term. Credit four hours. Continuation of Mechanics 220. Prerequisite course, Mechanics 220. Mechanics of materials including stress and strain, tension, shearing, compression, torsion, flexure; elastic curves; safe loads; columns; flexure of beams by semi-graphic treatment. Review problems showing application of principles in Engineering Design. Four recitations a week. Professors GEORGE and RETTGER, and Assistant Professor HOWELL.

221-A. **Mechanics Laboratory.** Credit one hour. One two-and-one-half hour period a week. Experiments designed to illustrate the principles of mechanics studied in Course 221. Courses 221 and 221-A are closely correlated and must be taken concurrently. Professors GEORGE and RETTGER, and Assistant Professor HOWELL.

222. **Advanced Mechanics.** Elective. Seniors and graduates. First term. Credit three hours. Prerequisite courses 220 and 221. Following a brief general review of fundamental topics in Mechanics of Materials, this course covers: induced stresses; torsion; unsymmetrical bending; torsion of prisms of non-circular section; hoops; flat plates; localized stresses; theory of least work; internal work

and its derivatives. Recitations, three hours a week. Professors GEORGE and RETTGER.

223. **Engineering Problems.** Seniors. Either term. Credit two hours. Prerequisite courses 220, 221 and 240. The object of this course is to provide a review involving additional practice in using the principles and methods of applied mechanics. A series of problems, such as occur in ordinary engineering practice, and covering a wide range of topics, is given out for solution. Computations and reports. Five hours a week. Professors GEORGE and RETTGER, and Assistant Professor HOWELL.

224-A. **Engineering Mathematics.** Primarily for graduate students. Prerequisite, Mathematics 5b. First term. Credit three hours. An elementary course in ordinary differential equations with applications to engineering problems. Hyperbolic functions, trigonometry, advanced calculus and advanced algebra are dealt with insofar as this is necessary for a clear understanding of the processes of differential equations. The purpose of this course is to lay the foundation for course 224-B. Professor RETTGER.

224-B. **Advanced Engineering Mathematics.** Second term. Credit three hours. Special emphasis is given to partial differential equations. Laplace's equation is derived and is applied to engineering problems. Vector analysis and complex variable in engineering problems. Professor RETTGER.

228. **Theory of Elasticity.** Primarily for graduate students. Second term. Credit, four hours. Prerequisite, 224-A. Theories of elastic breakdown. Fundamental relations of stress and strain; Airy stress function. Problems in two-dimensional and three-dimensional stress and strain. Analogies and their application to solutions of engineering problems in elasticity. Professor HOLLISTER.

229. **Experimental Elasticity.** Primarily for graduate students. Second term. Credit dependent upon approved work done. To be preceded or accompanied by Course 228. Experimental study in applications of the theory of elasticity to engineering problems. Investigations of stress concentrations and distributions by (a) photo-elastic analysis; (b) model analysis based upon the membrane, electrical, slab, or other analogies; (c) model tests. Professor HOLLISTER.

MATERIALS OF CONSTRUCTION

225. **Materials of Construction.** Juniors. Either term. Credit three hours. Prerequisite course 221. The materials studied are: Lime, cement, stone, brick, sand, timber, ores, cast iron, wrought iron, steel, and some of the minor metals and alloys. The chemical and physical properties, uses, methods of manufacture, methods of testing, and unit stresses of each material are considered, particular emphasis being laid on the points of importance to engineers. Three recitations a week. Textbook: Mill's *Materials of Construction.* Professor SCOFIELD and Mr. VANDERLIP.

226. **Materials Laboratory.** Juniors. Either term. Credit three hours. Prerequisite course 221 and must be taken with or preceded by 280. Experimental determination of the properties of materials by mechanical tests. Study of testing machines (their theory, construction, and manipulation); calibration of testing machines and apparatus; commercial tests of iron and steel; tensile, compressive, torsional, shearing, and flexure tests of metal and various woods with stress-strain observations; tests of cement, concrete aggregate, concrete, plain and reinforced, and of road material and paving brick. The course is planned to supplement Course 225 with its study of the properties of materials by the actual handling of the materials and by observations of their behavior under stress. Laboratory work five hours a week. Professor SCOFIELD and Mr. VANDERLIP.

226-A. **Materials Laboratory.** Given especially for Juniors in Administrative Engineering. Either term. Credit two hours. Prerequisites Course 221 and must be taken with or preceded by Course 280. A brief course in the study of material testing technique and the properties of the more common materials of construction. Professor SCOFIELD and Mr. VANDERLIP.

227. **Testing of Materials.** (Laboratory.) First term. Credit one hour. Given especially for students in the College of Architecture. A brief course in laboratory methods comprising test of beams and columns in steel, wood, and concrete. Professor SCOFIELD.

HYDRAULIC ENGINEERING

230. **Water Supply.** Seniors. Either term. Credit three hours. Prerequisite course 240. Three recitations a week from assigned texts and the working of assigned problems. About half of the term is devoted to the methods of making the preliminary investigations for a hydraulic development involving the use of a stream or the ground water; general hydrology; water resources of a basin; methods of systematic stream gaging; stream characteristics; working up data; use of mass curves in storage studies; percolating waters; probable dependable draft; flow into wells, etc. The second half of the term is devoted to a review of the methods of developing public water supplies from the several sources; typical structures; a study of the working conditions and fundamental data for designing conduits; distributing reservoirs; and a network of street mains; particular attention being given to the requirements for fire protection and the economics of pumped supplies. In the problems applications of the text are made to particular localities, the topographic maps of cities and drainage basins forming the bases of the problems. Students contemplating extensive election of courses in hydraulics should arrange to take this course the first term. Courses, 231, 232, and 233 are elaborations of details in this course. Professor SEERY.

231. **Hydraulic Construction.** Elective. Seniors and graduates. Second term. Credit three hours. This is a computing and designing course dealing with problems of water storage and the design and construction of dams by means of lengthy problems to be solved by graphical and analytical methods, and involving the economics of water storage at a given site, the design of a high masonry dam by Wegmann's Method and the tests for safety and stability of design, and the design of a weir dam of reinforced concrete and the analysis of stresses and stability. Professor SEERY.

232. **Water Power.** Elective. Seniors and graduates. Either term. Credit three hours. Three lectures and recitations a week and the working of three lengthy problems during the term. The subject matter of the course is to be found in the text used, Mead's *Water Power Engineering*, and covers the technique of hydraulic turbines, the analysis of test data, study of the adaptation of turbine types to working conditions, unsteady flow and surging in long conduits, governing, and the analysis of the power available at a low head millsite. Professor SEERY.

233. **Hydraulic Engineering.** Elective. Seniors and graduates. Credit three hours. First term. Lectures, recitations and abstracting of references relating to soil technology and theory of percolating water, recent developments in the design and construction of earthen dams and levees; theory of design of gravity and arch masonry dams and distribution of stresses in such structures; spillway design; preparation of dam sites; construction methods and plants. Professor SEERY.

234. **Conservancy and Reclamation Problems.** Elective. Seniors and graduates. Credit three hours. Second term. Lectures, recitations and abstracting of references relating to flood flow estimates; planning for and designing of flood protection structures, irrigation and drainage works. The Miami Conservancy work will be the chief source of material for the course. Professor SEERY.

236. **Water Power and Pumping Plants.** Elective. Seniors and graduates. Second term. Three hours credit. This is a computing and designing course devoted to the problems of designing and detailing power and pumping plants. Prerequisites, courses 230 and 232. Professor SEERY.

THEORETICAL AND EXPERIMENTAL HYDRAULICS

240. **Hydraulics.** Juniors. First term. Credit four hours. Prerequisite courses 220 and 221. Three recitations and one laboratory period a week; about one-quarter of the recitation periods are utilized for experimental demonstrations. Hydrostatic pressure; manometers; strength of pipes; stability of dams; immersion and flotation; flow of liquids through orifices, nozzles, Venturi meters, and pipes, and over weirs; time required to empty tanks and reservoirs; simple, compound, branching and looping pipes; elementary power calculations in common pumping and fire protection problems; flow of water in open channels; pressure on stationary solids due to deviated flow. Elementary consideration of modern water wheels. Professors SCHODER and WALKER, and Mr. PENDLETON.

240-A. **Hydraulics.** Juniors in Administrative Engineering in Civil Engineering. Second term. Credit three hours. Prerequisite courses 220 and 221. Three recitations a week. About one-quarter of the recitation periods are utilized for experimental demonstrations. The topics covered are the same as stated under course 240, but there is no laboratory work. Professor SCHODER.

241. **Advanced Hydraulics.** Elective for seniors and graduates. Second term. Credit three hours. Prerequisite course 240. Lectures, recitations, and reports. The recitations and problems take up topics in stability of flotation; overflow dams free and submerged; backwater and variable flow in open channels; standing waves; water hammer and surges; viscous flow of fluids and flow of air in pipes; impulse wheels and turbines; centrifugal pumps; hydraulic rams. Professor SCHODER.

242. **Hydraulic Measurements.** Elective for seniors and graduates. First term. Credit three hours. Prerequisite course 240. Three periods a week in laboratory or computing room. Experimental studies on weirs, Pitot tubes, pipes, current meters, fire hose and nozzles, ordinary water-meters, floats in open channels, actual measurement of river or canal discharge and such occasional tests as opportunity offers in the laboratory or the immediate neighborhood of Ithaca. The determination of efficiency, capacity, and characteristics of hydraulic machinery by tests. Professor SCHODER.

MUNICIPAL AND SANITARY ENGINEERING

250. **Sanitary Biology.** Elective. Juniors and seniors. Second term. Credit three hours. The course is designed to familiarize the student with current standard practice in the bacteriological control of water and sewage treatment plants. The use of the microscope; preparation of media; bacteriological analyses of water, sewage, sewage effluents and sewage sludge; efficiency of disinfectants; and that part of the science of bacteriology related to sanitary engineering. Textbook: Buchanan's *Household Bacteriology.* One recitation and two laboratory periods a week. Professor WALKER.

251. **Sanitary Biology.** Elective. Juniors and seniors. First term. Credit two hours. The collection and microscopical examination of the various forms of algae most prevalent in water supplies; the methods of their identification and control; and a study of the biological forms most prevalent in sewage wastes and sludges. Lectures, notes, and various references. One laboratory period a week. Professor WALKER.

252. **Municipal Sanitation.** Juniors. Second term. Credit four hours. Prerequisite course 240. Three recitations and one computing period a week. Sewer design and construction, and sewage disposal. Problems illustrating the matter taken up in the recitations such as problems on sewage flow, both domestic and storm water; hydraulic problems; construction problems dealing with various details of disposal plants. Textbook: Babbitt's *Sewerage and Sewage Disposal.* Four sections. Professors OGDEN and WALKER.

252-A. **Municipal Sanitation.** Required of seniors in Administrative Engineering. Credit three hours. A shorter course covering a field similar to that of 252. Professors OGDEN and WALKER.

253. **Purification and Control of Water Supplies.** Elective. Seniors and graduates. Second term. Credit three hours. Prerequisite course 230. Examination of water (physical, chemical, and bacteriological); normal quality of surface and subterranean waters, with effects of storage; communicable diseases and water supplies; epidemics of typhoid fever and cholera with studies of etiology, etc.; purification of water, sedimentation, and coagulation; slow sand filtration (theory, construction and operation, with examples); rapid sand filtration (theory, construction, and operation, with examples); miscellaneous purification processes (aeration, softening, iron removal, sterilization, distillation, and purification by chemicals). Professors OGDEN and WALKER.

254. **Sewerage Works.** Elective. Seniors and graduates. First term. Credit three hours. Prerequisite course 252. Three hours a week for fifteen weeks, divided between lectures and recitations. The work is upon the construction and operation of sewers and sewage disposal works, illustrated by lantern slides and by reference to recent descriptions of sewage-disposal plants in the current literature. There are, generally speaking, three recitations or one week's work on each of the following topics: disposal by dilution (salt and fresh water); chemical precipitation; broad irrigation, with special reference to institutions; natural and artificial filtration beds; sedimentation and septic tanks; Imhoff tanks; contact beds; sprinkling filters; and activated sludge. It is intended to differentiate this course from the junior work by making the latter chiefly a discussion of principles involved, while the senior course is a detailed investigation of the methods of construction with the reasons involved. Textbook: Metcalf and Eddy's *Sewage Disposal.* Professor OGDEN.

255. **Treatment of Wastes.** Elective. Seniors and graduates. First term. Credit three hours. Prerequisite course 252. The treatment of municipal and industrial wastes such as from garbage plants, tanneries, slaughter-houses, mines, canning factories, sugar factories, dye plants, pulp mills, creameries, cheese factories, milk bottling stations, and condensaries is considered.

Flow or process charts for each industry are used to show the general character, and composition of the wastes; and methods of treatment applicable, including results of experimental work, are considered. Professor WALKER.

256. **Municipal Engineering.** Elective. Seniors and graduates. First term. Credit three hours. A study of the relationships that exist between the practising municipal engineer and the various state and city commissions and other organizations with which he comes in contact. Financing of municipal operations including bond issues and sinking funds; special assessments; the limitations and restrictions placed by State Departments on municipal enterprises; town planning and public utilities; municipal housekeeping. Lectures, reports, and readings. Professor OGDEN.

257. **Purification of Water.** Elective. Graduates. Credit three hours. Specific problems in water purification; control of watersheds; effect of sedimentation on waters of different compositions; treatment of waters for particular requirements, such as removal of hardness, sediment, bacteria, etc. A report on some existing water system will be required from each student. Professor OGDEN.

258. **Conference on Present Methods of Sewage Disposal.** Elective. Graduates. Credit three hours. A critical study of the construction and operation of plants now in existence. Inspections and reports. Professor OGDEN.

259. **A Laboratory Course for Graduates.** Devoted to some special problem of sewage or water, such as the operation of a water-filtration plant, a sewage-disposal plant, the purification of trade wastes, the value of disinfection, etc. Professors OGDEN and WALKER.

TRANSPORTATION ENGINEERING

260-A. **Location Surveying.** Juniors. See Course 213. One week during summer vacation, opening date to be announced. Credit one hour. Each section is required to make complete preliminary and location surveys for a line two or

three miles long. In this work the section is divided into level, transit, topography, and cross-section parties, as the different phases of the work are encountered. Finally structure and right of way surveys are made. The assignments of the men are changed every day so that each student receives practice in the various kinds of field work. Professor BARNES, Assistant Professors PERRY and THATCHER, and Mr. SPRY.

260-B. **Route Surveying and Drawing.** Juniors. Either term. Credit three hours. One recitation and two field or drawing periods a week. Prerequisite courses 213 and 260-A. The recitations cover the theory of simple, transition, and vertical curves, and earthwork computations; with applications to practical problems for purposes of illustration. The field periods take up about two-thirds of the term and are devoted to computing, laying out and checking simple, transition, and vertical curves. Each section is divided into parties of three so that each student obtains more individual instruction, more practice in handling instruments, and a more intimate knowledge of the problems than he would in larger parties. The drawing periods take up the remaining third of the term and in them each student makes a pencil map of the preliminary line surveyed by his section in 260-A and prepares a detailed "paper location" report based on these data. A tracing and profile of the final location as run in the field is then required, also a computation of part of the earthwork. Professors BARNES and CONWELL, Assistant Professors PERRY, CRANDALL, and THATCHER.

260-C. **Route Surveying and Drawing.** Juniors in Administrative Engineering. First term. Credit two hours. One recitation and one field or drawing period a week. Prerequisite courses 213 and 260-A. An abridgement of course 260-B. Professors BARNES and CONWELL and Assistant Professors PERRY, CRANDALL, and THATCHER.

261. **Railroad Maintenance of Way.** Elective. Seniors and graduates. First term. Credit three hours. Prerequisite course 260-B. The subjects treated are track materials (with special reference to the section, method of manufacture and composition of steel rails, to the economics of tie preservation and the use of metal ties, and to the effect of quality of ballast upon maintenance); machine and other methods of grading for second track; drainage; track laying by both machine and hand methods; ballasting and bringing new track to line and grade; turnouts and switches; derailing switches; side tracks and yard tracks; sorting and terminal yards; track maintenance; track tools, work trains; action of car wheels on curves; widening of gage; double tracking; separation of grades; and improvement in grades and alinement. Lectures and recitations three hours a week. Professor BARNES and Assistant Professor PERRY.

262. **Railroad Operation and Management.** Elective. Seniors and graduates. Second term. Credit three hours. Prerequisite course 260-B. Under organization the following subjects are treated: general principles underlying organization and the effect of each on efficiency; principal departments of railway service with a brief outline of the work of each; departmental and divisional systems of organization, with examples on various roads and discussion of adaptability of each. The duties of officers and the work of the different departments are taken up in considerable detail. The most important laws affecting railroads are given in discussing the work of the legal department. Freight traffic, freight houses, classification yards, car service rules, accounting, etc., are among the topics considered under operation. Signaling and interlocking and train rules are also considered. Lectures and recitations three hours a week. Professor BARNES and Assistant Professor PERRY.

263. **Railroad Location.** Elective. Seniors and graduates. Second term. Credit three hours. A detailed study is made of the economic principles governing the location of new railroads, both steam and electric, and the revision or relocation of existing lines to make them most efficient as transportation machines. Some of the topics treated are estimation of revenue, expenses and rates and steam and electric locomotive performance and train operation; gradients, distance and curvature; line and grade revisions; grade crossing elimination and additional

facilities; location surveys and estimates. Lectures and recitations with problems involving investigations of projects, revisions and comparisons of alternate locations. Three hours a week. Professor BARNES.

264. **Engineering Construction.** Sophomores. Either term. Credit three hours. A fundamental course designed to acquaint the student with the financial and economic principles underlying human enterprises, both public and private; and with the agencies, money, men, materials and machines, utilized in carrying out construction projects, and their correlation and control. About one-third of the term is devoted to such topics as the history of engineering and the rôle of the civil engineer in the progress of civilization, cooperation with other professions, day labor and contract methods of control, types of contracts, elements of cost including depreciation and overhead, life and economic selection of structures, planning and plant layouts including the plotting and use of the Mass Diagram. The other two-thirds of the term are devoted to the methods and processes of construction with special attention to the equipment available and its adaptability to various kinds of work. Problems and reports on references to periodical literature are required of all students. Professors BARNES and CONWELL and Assistant Professors PERRY, CRANDALL, and THATCHER.

265. **Highway Engineering.** Seniors and graduates. Either term. Credit three hours. Prerequisite courses 260-A and 260-B. The course consists of lectures and recitations considering the economics of location, modern tendencies and methods of design, economic selection of routes and types of surfaces, subgrade soils, drainage, finance, and the technique of construction and maintenance of flexible and rigid types of pavements. In addition to the class work a problem is assigned which requires a complete redesign for modern traffic conditions of an old highway. Professor CONWELL and Assistant Professor THATCHER.

266. **Highway Laboratory.** Elective. Seniors and graduate students. Either term. Credit three hours. Prerequisite course 265 or may be taken concurrently with course 265. Subgrade soils are sampled and their properties examined in the laboratory. Tests are also made of various soils used with bituminous materials to determine their suitability for use in highway work; sheet asphalt and other mixtures are designed and examined for stability, etc. Professor CONWELL and Assistant Professor THATCHER.

267. **Advanced Highway Engineering.** Elective. Seniors and graduate students. Second term. Credit three hours. Prerequisite course 265. This course is conducted as a seminar. Meetings are held once each week during an afternoon or evening. The topics for assignment and discussion include the economics of highway engineering, design, construction, and maintenance of highways, the latest research programs and reports, labor and plant organization for various kinds of highway contracts with especial emphasis on the economics of contracting, highway finance, legislation, regulation, etc. Professor CONWELL.

268. **Advanced Highway Laboratory.** Elective. Seniors and graduate students. Either term. Credit three hours. Prerequisite courses 265 and 266. Testing of non-bituminous and bituminous highway materials and a study of their characteristics; testing of aggregates, soils, bituminous concrete, sheet asphalt, and asphalt paving block mixtures; study of specifications. Special investigations and tests are made to determine the properties of various combinations of materials and the effects of modifications in design. Two laboratory periods a week. Professor CONWELL and Assistant Professor THATCHER.

269. **Transportation.** Second term. Required of seniors in Administrative Engineering and may be elected by other qualified seniors, and graduates. A course covering travel and transport agencies with special reference to their facilities, ownership, financing, regulation and coordination. A brief review of the development of transportation throughout the world is used as a background for an intensive study of the present situation in the various countries and comparison of the policies and practices in use. Particular attention is given to the various proposals designed to promote more efficient use of the various transportation

agencies in the United States by better coordination, pooling of facilities etc., and economic studies are made of some of the new projects which are under discussion. Professors BARNES and CONWELL.

STRUCTURAL ENGINEERING

270. **Stress Analysis and Structural Design.** Juniors. Either term. Credit four hours. Prerequisite courses 220 and 221.

Stress Analysis. Graphic Analysis of simple and cantilever beams, roof trusses, and framed bents. Determination of position of moving concentrated loads for maximum shears and moments in beams and deck girders. Also for through girders and maximum floor beam reactions for same. Stresses due to dead load, live load, impact, and wind load in the principal types of simple trusses employed in modern construction. Stiff web systems and counter bracing. Three-hinged roof and bridge arches. Practical problems in actual stress computation throughout the course. Textbook: Urquhart and O'Rourke's *Stresses in Simple Structures.* Three recitations a week.

Structural Design. Graphic analysis of stresses in a timber truss. Design of truss members and joint details. Computations, systematically arranged in the form of reports, and working drawings. Textbook: Jacoby and Davis' *Timber Design and Construction.* Computation and drawing, two and one-half hours a week. Professor URQUHART, Assistant Professors BURROWS and O'ROURKE, and Mr. PENDLETON.

270-A. **Structural Analysis.** Juniors in Administrative Engineering. First term. Credit two hours. Prerequisite courses 220 and 221. Graphic analysis of simple and cantilever beams, roof trusses, three-hinged roof arches, and framed bents. Analysis of stresses in through and deck girder bridges, due to dead and moving concentrated loads. Textbook: Urquhart and O'Rourke's *Stresses in Simple Structures.* Two recitations a week. Professor URQUHART and Assistant Professors BURROWS and O'ROURKE.

271. **Structural Design.** Juniors. Either term. Credit three hours. Prerequisite course 270 or 270-A. An elementary course in Steel Design. Complete designs and detail drawings of the steel skeleton of a small building, including trusses, and of a through plate girder bridge. Textbook: Urquhart and O'Rourke's *Design of Steel Structures.* Three computation or drawing periods a week. Professor URQUHART and Assistant Professors BURROWS and O'ROURKE.

272. **Higher Structures.** Elective. Seniors and graduates. Either term. Credit three hours. Prerequisite course 270. Stress analysis of continuous beams, framed bents and rigid frames. Horizontal as well as vertical loading considered. Redundant structures including the braced two-hinged arch. Displacement diagrams for trusses and arches and analytical computation of deflections of such structures. Three recitations a week. Professor URQUHART and Assistant Professor O'ROURKE.

273. **Steel Buildings.** Elective. Seniors and graduates. First term. Credit three hours. Prerequisite courses 220, 221, and 271. This course comprises the design of the steel framework for buildings of the prevailing type used in power house or shop construction. Dead, snow, and wind stress diagrams are drawn for the roof trusses. Provision is made for an electric crane moving the full length of the building and the stresses in the framework due to the movement of the crane are determined. The effect of the wind and the eccentric load due to the crane girder are considered in the design of the columns. Textbook: Ketchum's *Steel Mill Buildings.* Reports and drawings. Three two-hour periods a week. Assistant Professor BURROWS.

274. **Bridge Design.** Elective. Seniors and graduates. Second term. Credit three hours. Prerequisite course 271. Computations and drawings for the complete design of a railroad bridge of six or seven panels or a heavy highway bridge. The computations to determine the stresses and sections of all members, pins,

pinplates, splices, deflection, camber, and other details as well as of connecting rivets are to be written up in the form of systematically arranged reports. The drawings consist of general detail plans showing the location of all rivets as well as the composition and relation of all members and connections. The final report is to give a full list of shapes and plates, and a classified analysis of weight for the span. Textbook: Urquhart and O'Rourke's *Design of Steel Structures*. Computation and drawing, three two-hour periods a week. Assistant Professor BURROWS.

275. **Investigation of Existing Bridges.** Elective. Seniors and graduates. Second term. Credit three hours. Prerequisite course 271. Inspection of existing structures for the determination of sizes and conditions of plates and shapes. After full data have been obtained in the field, computations will be made to determine either the unit stresses under a specified load, or the safe load or rating according to standard specifications. Assistant Professor BURROWS.

280. **Concrete Construction.** Juniors. Either term. Credit three hours. Prerequisite courses 220 and 221. (Preferably taken concurrently with or preceded by course 225). Properties of plain concrete, elementary theory of reinforced concrete as applied to rectangular beams, slabs, T-beams, beams reinforced for compression, columns and footings. Shear, diagonal tension, and direct stress combined with flexure. Computations in the forms of reports on the design of a typical beam and girder floor panel and of a retaining wall. Detail sketches of sections and reinforcement required. Textbook: Urquhart and O'Rourke's *Design of Concrete Structures*. Professor URQUHART, Assistant Professor O'ROURKE, and Mr. PENDLETON.

281. **Foundations.** Juniors. Either term. Credit three hours. Prerequisite courses 220 and 221. Piles and pile driving, including timber, concrete, tubular and sheet piles; cofferdams; box and open caissons; pneumatic caissons for bridges and buildings, caisson sinking, and physiological effects of compressed air; pier foundations in open wells; freezing process; hydraulic caissons; ordinary bridge piers; cylinders and pivot-piers; bridge abutments; spread footings for building foundations; underpinning buildings; subterranean explorations; unit loads. Textbook: Jacoby and Davis's *Foundations of Bridges and Buildings*. Recitations, collateral reading in engineering periodicals, and illustrated reports. Three hours a week. Professor URQUHART and Assistant Professor O'ROURKE.

281-A. **Foundations.** Juniors in Administrative Engineering. Second term. Credit two hours. Similar to course 280 with most of the material on caissons omitted. Two hours a week. Professor URQUHART and Assistant Professor O'ROURKE.

282. **Reinforced Concrete Building Design.** Elective. Seniors and graduates. Either term. Credit three hours. Prerequisite course 280. Design of a reinforced concrete flat-slab building and investigation of various other types of floor systems for commercial buildings. Complete detail design for one building, including stairway, elevator shafts, penthouses, etc. Working drawings and steel schedules. Seven and one-half hours a week. Textbook: Urquhart and O'Rourke's *Design of Concrete Structures*. Professor URQUHART and Assistant Professor O'ROURKE, and Mr. PENDLETON.

283. **Fixed Arches.** Elective. Seniors and graduates. First term. Credit three hours. Prerequisite courses 270, 271 and 280. Theory of the curved beam; the closed ring; the fixed arch. Influence lines for arches of various forms. Selection of curvature of axis for various loadings. Effect of temperature and rib-shortening. Effect of plastic flow on stresses in a reinforced concrete arch. Design of a reinforced concrete arch and its abutments. Lectures, recitations, and computations. Six hours a week. Professor URQUHART and Assistant Professor O'ROURKE.

284. **Highway Bridges.** Elective. Seniors and graduates. Second term. Credit three hours. Prerequisite course 280. Design of short span bridges and their abutments. Comparison of the economy of steel and reinforced concrete

superstructures for bridges of this type. Reports and drawing. Assistant Professor O'ROURKE.

285. **Reinforced Concrete Design.** Elective. Seniors and graduates. Either term. Credit three hours. Prerequisite course 280. Theory and design of gravity, cantilever, and counterfort retaining walls. Design of footings: single and multiple columns of reinforced concrete, I-beam grillages. Design of bins and tanks, subsurface and supported on towers. Reports and sketches. Three two-hour periods a week. Professor URQUHART and Assistant Professor O'ROURKE.

286. **Building Construction.** Elective. Juniors, seniors, and graduates. Second term. Credit three hours. Lectures and quizzes. The general plan includes one lecture each week by a practicing engineer or architect well known in his particular field. This is followed by a supplementary lecture by a member of the University staff.

In 1933-34, the field covered included lectures on: The Field of the Consulting Engineer; the Conception and Execution of a Building Project; The Financial Plan in Building Operations; Fire Protection; Testing Materials; Building Codes; Licensing; Concrete and Reinforced Concrete; Foundations; Steel Frame Buildings and Their Erection; Welding; Exterior and Interior Finish; Synchronizing Operations; Maintenance and Remodeling; The State Building Program. Professor URQUHART and others. (Not given in 1934-35.)

ADMINISTRATIVE ENGINEERING

3A23. **Business and Industrial Management.** Second term. Credit four hours. Required of all Sophomores in Administrative Engineering. Four lecture-discussion periods a week with regularly assigned problems.

This course is intended as a survey of the problems of business and industrial organization. It deals with the establishment of business policies, types of business and industrial ownership, together with the functions of finance, control, machine production, personnel and marketing. Elementary consideration will be given to the problems of the selection of plant site, time and motion study, wage systems and the selection of personnel, all of which will be developed in greater detail in subsequent courses. Professor BANGS.

3A31. **Accounting for Engineers.** Second term, required of A.E. Sophomores. Credit three hours. Two recitations and one 2½-hour computing period a week. Theory of debits and credits; development of books of original entry; voucher system; analysis of financial statements; financial mathematics; negotiable instruments; budgetary control; modern mechanical methods of performing the accounting function. Mr. MILLARD and others.

290. **Engineering Law.** Seniors. Juniors admitted only by special permission. Also open to seniors in Architecture, Mechanical and Electrical Engineering, Chemistry, and other seniors submitting acceptable qualifications. Either term. Credit three hours. Essentials of contracts and contract principles; agency, tort and independent contractor; use and conveyance of lands and waters, including irrigation law, real estate documents, boundary lines, eminent domain and title searches; corporations, partnerships and other contracts of association; sales and transportation contracts; negotiable instruments; bankruptcy, mechanics liens, patents, trademarks, copyrights, courts, wills, and laws of insurance. The course culminates with the preparation of a set of contract documents for an assigned construction job, including advertisement, form of proposal, information to bidders, agreement form, and general conditions with clauses covering payments, time limit, arbitration, extras, liquidated damages and abandonment of contract. Tucker's *Contracts in Engineering* is used as a text, supplemented liberally from other sources. Lectures and recitations three hours a week. Professor BARNES, Assistant Professors CRANDALL, PERRY, and THATCHER.

290-A. **Advanced Engineering Law.** Second term. Credit three hours. Required of seniors in Administrative Engineering and open to others who have

completed course 290 of which this course is largely an extension. Some additional topics treated are municipal laws and ordinances, labor laws under various jurisdictions, reclamation and other laws concerned with the development of natural resources and compensation and insurance laws. Actual cases will be used for illustrating the above and also some of the topics treated in course 290. Professor BARNES and Assistant Professors PERRY, CRANDALL, and THATCHER.

293. **Engineering Management.** Seniors. Either term. Credit three hours. Also open to qualified seniors from other departments. This course is devoted mainly to the management of construction work but also treats briefly of such larger problems as economics of plant location and economic selection of plant, or structure, to fulfill a given purpose. Management is treated under its two main heads,—planning and operation. Under planning are such subjects as the selection of methods of procedure which will result in maximum economy, the planning of a thoroughly coordinated organization of men and machines to carry out these methods and the scheduling and estimating of the work in accordance with the adopted plans. Under operation are selecting, training and maintaining labor forces including pay systems, accident prevention, welfare work, etc., purchasing, operation and maintenance of equipment and keeping the records essential to the management for comparing results with schedules, i.e., cost keeping. Bookkeeping is recognized also as an essential tool of management and the fundamentals of double entry bookkeeping are given, together with the use of control accounts, financial statements and budgets. Blanks and forms for cost keeping for actual or assumed jobs are required and each student also works out problems in bookkeeping. Professor BARNES and Assistant Professor CRANDALL.

293-A. **Engineering Management.** Elective. First term. Seniors in administrative engineering option and others who have had accounting. Prerequisite, an elementary course in accounting. Covers the same ground as course 293 except that bookkeeping is omitted and more attention is given to management proper, especially to personnel and labor relations. Professor BARNES.

293-B. **Cost Accounting.** Second term. Credit three hours. Required of seniors in Administrative Engineering and open to others who have had an elementary course in accounting. A general course in cost accounting on engineering construction and operations involving estimating, bidding, planning and scheduling, control of job costs and effect of financing, time of construction and methods on costs. Professor BARNES and Assistant Professor CRANDALL.

294. **Technical Writing.** Sophomores. Either term. Credit three hours. A study of the written forms of expression used in engineering and in business. The sources of subject matter; the use of the library; logical organization and attractive layout of material; clear, concise, and accurate statement of ideas; the proper use of abbreviations and punctuation. The written work includes business letters, editorials, abstracts, summaries, short reports, and briefs for technical argument. Mr. BOYLES.

295. **Valuation Engineering.** Elective. Seniors and graduates. Second term. Credit three hours. Prerequisite courses 264 and 290 or taken concurrently with 290. Lectures, recitations, and reports. Theory and practice of valuation or appraisal for purposes of utility rate making, purchase or sale, eminent domain or condemnation cases, mergers or joint ownership, taxation and assessment, issuance of securities, bank loans, insurance, uniform system of accounting and improved management. Topics considered include scientific systems of real estate assessment, federal railroad valuation, rate disputes, court rulings, computation of actual rates for gas, telephone, electrical supply and street railways, valuation of land, mines, water power, factories, railroads, toll bridges, buildings, and all kinds of property both tangible and intangible. Detailed examples of forms and methods with outline of typical valuation reports. Assistant Professor CRANDALL.

REGIONAL AND CITY PLANNING

710. **Principles of Regional Planning.** Throughout the year. Credit two hours each term. Registration limited to 50. Open to graduates and upperclass-

men in all colleges of the University. A general view of the theory and practice of large scale planning. Lectures, assigned reading and examinations. Occasional lectures will be given by members of other faculties and by outside lecturers selected because of their special experience and skill in certain phases of planning. Students wishing to register for this course should register with Mr. Clarke at the College of Architecture on registration day. M W 12, *White* 33. First given in the second term, 1934-35. Professor CLARKE.

711. **Seminar in Regional Planning.** Throughout the year. Credit one hour each term. Investigation of assigned topics on particular aspects of the subject with emphasis on regional planning. Registration limited. Open to students in all colleges of the University, by permission. This course should accompany or follow course 710. By appointment. *White Hall.* First given in the second term, 1934-35. Professor CLARKE.

712. **Seminar in Park Planning.** First term. Credit two hours. Specific problems relating to the design of city, state and national parks with a study of examples. Registration limited. Open to upperclassmen and graduates in the Colleges of Architecture and Engineering. By appointment. *White Hall.* First given in 1935-36. Professor CLARKE.

713. **Seminar in Parkway, Freeway, and Highway Planning.** Second term. Credit two hours. Specific problems relating to the design of the modern parkway, freeway, and highway with study of examples. Registration limited. Open to upperclassmen and graduates in the Colleges of Architecture and Engineering. By appointment. *White Hall.* First given in 1935-36. Professor CLARKE.

GENERAL COURSES

291. **Engineering Design.** Elective. Seniors. Credit three or more hours. The student may make complete designs in one of the following sub-divisions, subject to approval. Hours to be arranged.

(a) **General Civil Engineering.** Either term. Problems in practical design may be taken in any department, the work to be supervised by the department concerned in cooperation with the Department of Structural Engineering in regard to structural features.

(c) **Hydraulic Engineering.** Second term. Prerequisite courses 240 and 223. For best results Hydraulic Design should be preceded by Course 230, but the two may be taken concurrently. Courses 231 or 232 may be substituted for Engineering Design. One or both of these courses should be elected by the student specializing in hydraulics unless he has a good reason for electing independent design instead. The purpose of the course is not to duplicate in large part work regularly given in Courses 231, 232, and 241 or in the courses in structural engineering. Professor SCHODER.

(d) **Sanitary Engineering.** First term. This course must be preceded by or taken at the same time as Course 254, and may not be elected otherwise. The following problems indicate the scope of the work: (1) Computations, design, and detail drawings for the wooden forms needed for brick or concrete sewers of various diameters and forms of cross sections. (2) Computations, design, and detail drawings for a pile foundation to support sewers from three to ten feet in diameter. (3) Design and detail drawing for patterns of cast-iron manhole covers. (4) Computations, designs, and detail drawings for flap valve as outlet of settling tank, the design involving a lifting device. (5) Design and detail drawings of a sewage screen, involving a device for raising screen for cleaning. (6) Computations, designs, and a detail drawing for an inverted siphon for sewage flow; the problem involves a flushing gate and overflow as well as manholes. (7) Design of disposal plant for a small community as an asylum or school. Professor OGDEN.

(e) **Railroad Engineering.** Either term. The problems are those encountered in the location and construction of railroads, and include the following subjects: Economic location of railroads; culverts; bridges; retaining walls; tunnel and sub-

way design; small depot buildings; freight houses; water supply and coaling plants; icing stations; turntables and engine-houses; gravel washing plants; track layouts with details of signals and interlocking; yard and terminal design, etc. Bills of material and estimates of cost are usually required. The field is so broad that the interest of the student is given consideration in assigning problems. Professor BARNES and Assistant Professor PERRY.

(f) **Structural Engineering.** Second term. Course 271 is required as general preparation for engineering design in bridges and buildings. Course 272 is required in preparation for designs relating to draw, cantilever, suspension, and metallic arch bridges. Course 280 is similarly required for designs of bridges and buildings in reinforced concrete. Professor URQUHART and Assistant Professor BURROWS.

(g) **Highway Engineering.** Second term. The problems are those encountered in the location and construction of highways and include the following: Economic location; selection and design of different types of highway surfaces for various traffic conditions; culverts, bridges, retaining walls, and other highway structures. Bills of materials and estimates of cost are usually required, also plant layouts and methods of executing work. Professor CONWELL and Assistant Professor THATCHER.

296. **Earthwork Computations.** A special course for students in landscape architecture. Not open to students in civil engineering. See Announcement of the College of Architecture. Assistant Professor LAWRENCE

297. **Engineering Research.** Elective. Seniors and graduates. Credit three or more hours. Research may be taken in one of the following subdivisions or two or more departments may cooperate in the assignment of special problems. Hours to be arranged.

(a) **Geodetic Astronomy.** Second term. Prerequisite courses 184 and 216. Investigations of instrumental errors; variation of latitude and azimuth; any and all questions relating to work of the highest precision connected with astronomical problems and geodetic operations. The field is so broad that the interest of the student is given consideration as to the actual research undertaken. Professor BOOTHROYD.

(b) **Engineering Materials.** Either or both terms. Credit one hour for forty hours of actual work. A project may be started during the junior year for completion in the senior year. Prerequisite courses 225 and 226 or their equivalents. Special investigations of an advanced nature of the properties of structural units and the materials of construction. The aim of the course is to secure results by proper investigational methods which are of the caliber and scope deemed essential for publication. Professor SCOFIELD.

(c) **Experimental Hydraulics.** Either term. Prerequisite course 240 or its equivalent. The subject and scope of the investigations should be selected by conference at the beginning of the term if not previously arranged. It is often desirable and is permissible for two students to work together on the same investigation. Written reports are required but the text need not be typewritten in thesis style. These reports are kept by the department. In most cases it is necessary to arrange a definite schedule for work in the laboratory to avoid conflicts. Professor SCHODER.

(d) **Sanitary Engineering.** Either term. Prerequisites for work in this field will depend upon the particular problem to be pursued, but in general will include work in water analysis, bacteriology, and courses in Hydraulics and Sanitary Engineering dealing with the field in which the work is to be undertaken. Hours, credit for work, prerequisites and other questions relating to contemplated research in this field will be arranged by conference. Professors OGDEN and WALKER.

(e) **Railroad Engineering.** Either term. Special problems in the economics of location, construction, maintenance and operation of railroads, comparison of transportation agencies, traffic studies and economics of various systems of transport. Professor BARNES.

(f) **Structural Engineering.** Second term. Students wishing to pursue one particular branch of bridge engineering further than can be done in any of the regular courses may elect work in this field. The prerequisite courses depend upon the nature of the work desired. The work may be in the nature of an investigation of existing types of construction or theoretical work with a view to simplifying present methods of design or proposing new methods. Professor URQUHART.

(g) **Highway Engineering.** Either term. The laboratory for testing and investigating bituminous materials is available for research, and other materials may be tested in the laboratories in Lincoln Hall. Special problems in location and design and in economic selection of types of surfaces give opportunity for a wide variety of research. Professor CONWELL.

298. **Thesis.** Elective. Seniors. Credit three hours. The thesis is intended to demonstrate the ability of the student for independent investigation, or his ability to apply the fundamental principles acquired in his course to the study of some special problem related to civil engineering. The latest date for filing the subject with the Director of the School is October 15 for the first term, and January 15 for the second term. The plan of work is to be submitted to the professor having charge of the subject, to whom also regular reports are to be made showing the progress of the investigation. The latest date for presenting the complete thesis is June 1. A pamphlet containing instructions in regard to theses in Civil Engineering is available and should be consulted by students registered for this course.

SPECIAL AND GRADUATE COURSES

All the elective courses are suitable for graduate and advanced students, and may be taken by them in the regular classes. Other special courses will be arranged to suit the requirements of graduate students. These courses are intended to be pursued under the immediate direction of the professor in charge, the student usually being free from the restriction of the classroom, and working either independently or in conjunction with others taking the same course.

SIBLEY SCHOOL OF MECHANICAL ENGINEERING

OUTLINE OF THE INSTRUCTION

The instruction in Mathematics, Chemistry, Physics, English, and Economics is given in the College of Arts and Sciences. All other regular subjects in the course are of an engineering nature and are given in the Sibley School of Mechanical Engineering in the following departments: (1) Mechanic Arts; (2) Machine Design; (3) Mechanics of Engineering; (4) Heat-Power Engineering; (5) Experimental Engineering; (6) Industrial Engineering; (7) Administrative Engineering; (8) Aeronautical Engineering; or in the Schools of Electrical Engineering or Civil Engineering.

The following is a brief outline of the scope and purposes of instruction in the various departments of the School of Mechanical Engineering.

1. Mechanic Arts

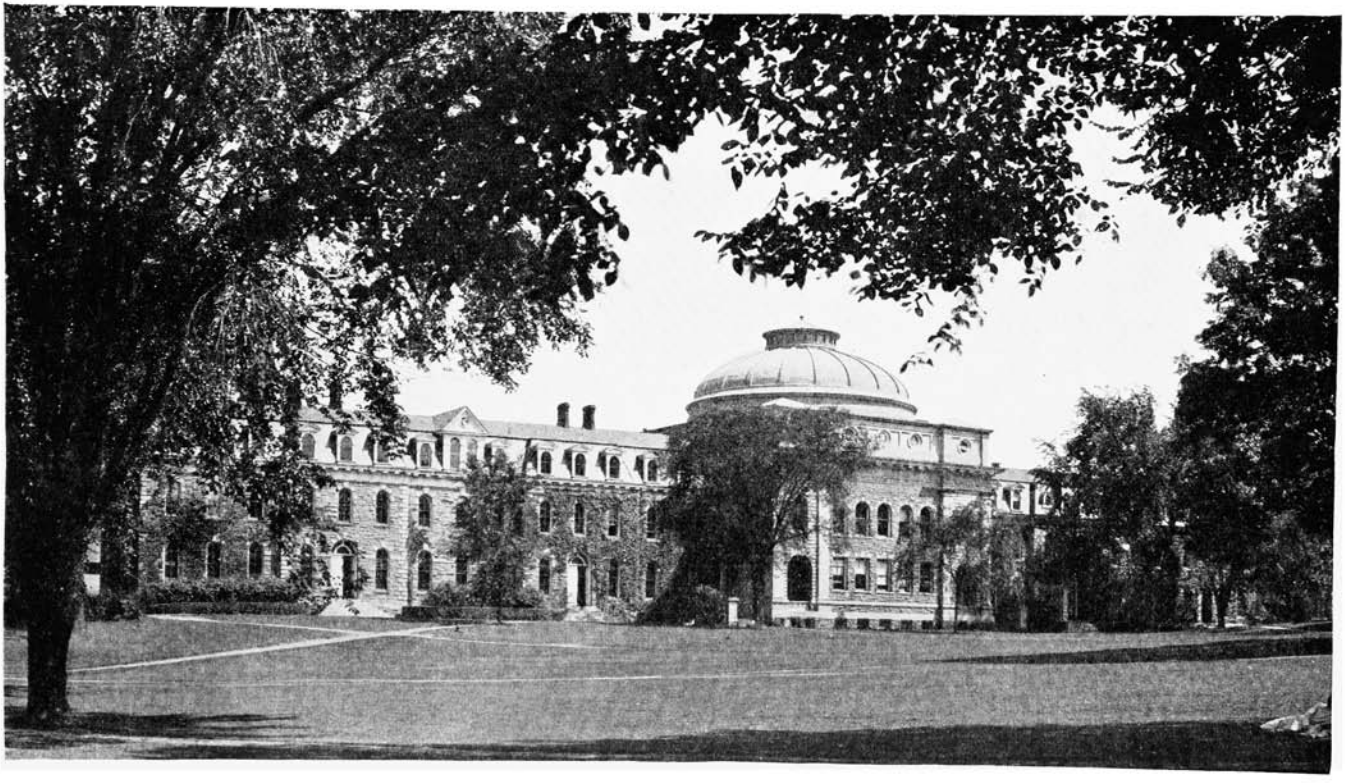
The object of the instruction in this department is not only to familiarize the student with modern shop operations and processes, and with the workability of materials used in engineering construction but more particularly to give him instruction in the principles of manufacturing and duplication of parts, and in the selection and arrangement of shop equipment.

The work of the freshman year in the shops is given in a laboratory course and in the wood shop. The laboratory course is designed to familiarize the student with current engineering terms and common engineering appliances. This course also includes some work in the forge shop illustrating the principal forge shop operations, like welding, hot working, gas and electric welding.

Instruction in wood-working is given with the object not only of familiarizing the student with wood-working tools and machines and their use, but more especially to teach him pattern and core-box making. Instruction is also given in large pattern work and sweep-work.

In the sophomore year the student receives instruction in the foundry in molding, core making, mixing of metals, operation of cupola, the uses of moulding machines, etc., with consideration given to the methods and appliances for sweep-work, large work, and production in quantities.

In the junior year the principles of manufacturing are taught, supplemented by work of an illustrative character in the machine shop, where carefully graded instruction is given in the use of measuring instruments, hand tools, and machine tools, including semi-automatic and automatic machines, and in the use of jigs and special fixtures for manufacturing in large quantities. The administration



THE SIBLEY SCHOOL OF MECHANICAL ENGINEERING

of this shop in particular is intended to illustrate as far as possible approved methods of shop management and operation, and to give the students a general idea of time keeping, piece work, premium plan, and other wage systems. The instruction is given to a great extent in connection with the construction of commercial machines.

2. Machine Design

In this department, instruction is given in empirical design, kinematics, and machine design, to sophomores and juniors in mechanical, electrical, and administrative engineering. Instruction in machine design is also given to seniors in chemical engineering. The department also offers elective courses open to sophomores, juniors, seniors, and graduates.

Instruction is given by means of recitations and work over the drawing board. First, a study is made of the common machine parts and their uses and the empirical proportioning and assembling of such parts. The study of kinematics is then taken up and applied to the solution of cam, gear, linkage, instant center, velocity, and acceleration problems. These courses are followed by recitations and drawing room courses in general machine design. The theory and principles developed are applied to the solution of many short problems and to the design of complete machines in the drawing room. Only such machines as lend themselves to rational analysis to the greatest degree are selected. The calculations are regarded as an important part of the work and the student's design is criticized from the standpoint of appearance, cost, convenience and economy of shop operations, lubrication, accessibility, ease of assembly, economy of upkeep, etc.

3. Mechanics of Engineering

In this department instruction is given in theoretical and applied mechanics and hydraulics, beginning with a course for sophomores in the fundamental principles of statics, kinetics, strength of materials and hydraulics. An effort is made to teach students to think rather than to memorize. With this in view the free-body method is used in the solution of problems involving forces, and students are required to work from fundamental definitions and principles rather than from formulas.

For juniors in Mechanical Engineering a course in advanced mechanics is given. This is designed to prepare the student for work in elasticity, photo-elasticity, and stress analysis, both theoretical and experimental. For seniors elective courses on hydraulic power plants are offered. While the theory of turbines is outlined, stress is laid upon the practical side of the subject, the object being to make the course of definite value for those expecting to take up hydroelectric work. The laboratory instruction in hydraulics is given in the Department of Experimental Engineering.

4. Heat-Power Engineering

Instruction in this department is given to all students of Mechanical Engineering in their junior and senior years, with the object of training them in the methods of solution of problems involved in the theory, design, performance, and economics of heat engines and their auxiliary apparatus, considered both separately and in combination in power plants.

The work begins with lectures and recitations on the elements of Heat-Power Engineering, including the study of the elementary thermo-dynamics of gases and vapors, ideal and actual cycles, air compressors, internal combustion engines, and steam engines. This is followed by a study of steam turbines, fuels and combustion, furnaces, steam generating units, draft apparatus, heat transmission, condensers, feed-water heaters and other power-plant auxiliaries, the flow of gases and vapors, the utilization of waste heat, refrigeration, and other topics.

In addition to taking these required courses, the student in his senior year may specialize in power plants or in fluid flow, heat transmission, air conditioning, and refrigeration, by taking the lecture and computing courses specially devoted to these subjects. He may also attend special lecture courses on steam turbines, steam-generating equipment, internal combustion engineering, and power plant economics.

5. Mechanical Experimental Engineering

A. Mechanical Laboratory

Instruction in this department begins in the sophomore year with the study of materials of engineering, their manufacture, properties, and uses.

Throughout the junior and senior years the student receives instruction in the very completely equipped mechanical laboratories (described on page 22), not only to familiarize him with the various types of testing apparatus and to give him skill in their use, but to teach him the best methods of research. Briefly, the courses include: the use of computing machines; the testing of engineering materials, with determination of influences of composition and heat treatment; the calibration and use of indicators, gauges, thermometers, dynamometers, etc.; tests of lubricants; fuel calorimetry; steam calorimetry; valve setting; tests of boilers, steam engines, turbines, pumps, heaters, condensers, injectors, and other steam apparatus; tests of air compressors and refrigerating machines; tests of external and internal combustion gas and oil engines; and tests of hydraulic machinery.

B. Experimental Engineering Research

Experimental Engineering research by graduate and undergraduate students is carried on in this department under the supervision of a separate corps of specialists who devote their entire time to this work.

Students who have shown proficiency in experimental engineering may have opportunity to conduct original investigations under expert guidance, and as occasion offers, may assist in commercial tests, made at the University or elsewhere, of materials, prime movers, power plants, etc. The equipment of every department is available for this work and the specialists in any department may be consulted.

In case the investigation or research is sufficiently extended, the student is encouraged to embody the work in a thesis. Research, or Thesis, may be elected during the senior year by a limited number who have shown special ability for investigation. Arrangements for this work should be made with the department during the junior year if possible.

This department will cooperate in every way to assist graduate students in mechanical, electrical, and industrial engineering, and will aid in providing apparatus and other facilities for graduate work.

6. Industrial Engineering

In the junior year all students in Mechanical and Electrical Engineering receive instruction in industrial history and the present principles and tendencies of industrial engineering.

For seniors in Administrative Engineering and seniors in Mechanical Engineering who elect the Industrial Option more advanced work is provided. The principles governing manufacturing methods are studied and a layout made for a modern manufacturing industry. Methods of production and material control are studied, as well as organization and methods of expense distribution. The subject of time and motion study is presented including micro-motion study and the principles of motion economy. The department conducts a micro-motion laboratory equipped with the necessary motion-picture equipment.

The course in Industrial Relations includes a consideration of the human problems of management such as organized labor, labor legislation, employee health, wage payment, employee selection, etc.

The subject of cost-accounting is treated in coordination with the above subjects including principles and practise of standard, process and order costs.

7. Administrative Engineering

It is recognized that the four functions of business and industry are Marketing (including selling and advertising), Production, Finance, and Accounting. Accordingly, a basic course in Business and Industrial Management is given in the sophomore year to orient the student in commercial thinking. This course is paralleled by one in basic economics. Upon these two courses are built a series of carefully coordinated courses in English, Technical Writing, Accounting, Cost Accounting, Corporation Finance, Public Speaking, Industrial Relations, Statistics, Business Law, Industrial Engineering, Production

Management and Marketing. To supply the even closer contact with the outside world, a series of special lectures is given by business leaders who appear weekly before the senior classes.

The freshman year is the same as that given to all engineering students. During the next two years all students are required to take a balanced group of technical and economic courses. In the senior year a certain degree of specialization is permissible in either mechanical or electrical engineering.

About 68% of the course content, as given to the students in the M.E. and E.E. schools, is devoted to regular engineering subjects. This gives the course a substantial ground work in fundamental engineering; a prime requisite for the principles of scientific management so ably pioneered by Mr. Frederick W. Taylor. These principles have spread to almost every phase of human endeavor but their background is still engineering. The remaining 32% of the course is made up of subjects devoted to business and economics especially designed to fit the needs of modern industry.

8. Aeronautical Engineering

The College offers no complete four-year course in Aeronautical Engineering. The main reason for this is that under the Guggenheim Foundation, there are at the present time six or eight schools of engineering in the country offering such courses and the number of graduates annually turned out is more than sufficient to supply the field. In accordance with the recommendation of the Foundation, therefore, this College is offering a few courses in Aeronautics, beginning with the junior year and including an option in such work in the senior year. This amount of training in Aeronautics is believed to be sufficient to constitute a good foundation upon which to base advanced work in the same field in any one of the schools offering complete curricula in Aeronautics.

Non-Resident Lecturers

Supplementing the regular course of instruction, lectures are delivered from time to time by non-resident specialists in the profession on various subjects relating to the many branches of mechanical engineering. Seniors are required to attend these lectures. The student may also attend the many public scientific lectures given in other departments of the University by non-resident lecturers.

COURSES LEADING TO THE DEGREE OF MECHANICAL ENGINEER

1. The Regular Four-Year Course

One hour of credit in the following schedules corresponds to about three hours of actual work a week for the term of fifteen weeks. Thus, from two and one-half to three hours a week of actual work in shop,

laboratory, computing room, or drawing room count as one hour of credit, and each recitation hour assumes about two hours of outside preparation.

THE FRESHMAN YEAR

There is fundamentally a single schedule of studies prescribed for all students in the freshman year of the College of Engineering. That schedule is set forth in full under the head THE FRESHMAN YEAR, beginning on page 48.

THE SOPHOMORE YEAR

	Hours 1st Term	Hours 2nd Term
Mechanics 3M21	5	0
Strength of Materials 3M22	0	3
Hydraulics 3M23	0	2
Physics 21, 22	3	3
Kinematics, Recitations 3D21	2	0
Empirical and Kinematic Drawing 3D23	2	0
Kinematics, Recitations and Drawing 3D24	0	3
Materials of Engineering 3X21, 3X22	3	3
Economic Organization 3A21, 3A22	3	2
Pattern Shop 3S21	0 or 1	1 or 0
Foundry 3S22	0 or 1	1 or 0
Mathematics 3M24	0	2
Total number of hours each term	18 or 20	20 or 18

THE JUNIOR YEAR

	Hours 1st Term	Hours 2nd Term
Heat-Power 3P31, 3P32	3	3
E. E. Theory 415, 416	3	3
Machine Design, Recitations 3D31, 3D32	2	2
Machine Design, Drawing 3D33	0	3
Mechanical Laboratory 3X31, 3X32	4	3
Advanced Mechanics 3M31	3	0
Accounting 3A31*	0	3
Machine Shop 3S31	3	0
Industrial Organization 3I31	0	2
Total number of hours each term	18	19

*If Aeronautical Engineering is elected as a Senior Option, Aerodynamics 3M35 (2 hours) must replace this course in either the first or second term of the Junior Year.

THE SENIOR YEAR

In the Senior Year the student selects one of the following groups of studies. The major part of the work is the same in all of the groups, the difference lying only in the time devoted to certain special courses. After the selection is once made at the beginning of the first semester, no shift in the group selected will be permitted.

GROUP A

POWER-PLANT ENGINEERING

The object of the special courses in this group is to acquaint the student with load-curves and their characteristics, station factors, power-plant economics, and the cost of plants and of their component parts and output; the principles of the

economic selection and operation of the power-plant machinery with respect to character of the loading, the cost factors, and the local conditions involved; the design of steam power plant equipment with regard to these considerations and the structural requirements; plant location and layout; and similar topics.

The work is taught by lectures supplemented by a computing and layout course. In the latter the student, basing his work on a typical plant loading, makes an economic study of the requirements of the plant, and determines the sizes and types of equipment needed; analyzes the performance characteristics of the main apparatus; makes computations for and blocks out the principal design features and the arrangements of this equipment; selects the auxiliary apparatus; and plans the layout of the plant as a whole.

	Hours	
	1st Term	*2nd Term*
Heat-Power Engineering 3P41, 3P42	3	3
Mechanical Laboratory 3X41, 3X42	4	4
Electrical Laboratory 435, 436	2	2
Heating, Ventilating, and Refrigeration 3X44	3 or 0	0 or 3
Steam Power Plants Lectures 3P44, 3P45	2	2
Computing and Design 3P46, 3P47	2	2
Non-resident Lectures 3G41	0	1
Electives	3 or 6	5 or 2
Total number of hours each term	19	19

For suggested electives see list on page 87.

Group B

(Proposed for the academic year 1936-37)

Heat Engineering

(Fluid Flow, Heat Transmission, Air Conditioning, and Refrigeration)

To meet the demand for men trained in the fundamentals requisite for handling the great variety of problems encountered in the rapidly expanding fields of air conditioning, refrigeration, and industrial utilization of heat, it is planned to establish this Heat Engineering option in the fall of 1936. (In the mean time, briefer instruction in these fundamentals is offered in the following two-hour, elective courses: 3P48, Fluid Flow, Heat Transmission, and Air Conditioning, and 3P49, Refrigeration. Descriptions of these Elective courses are given on p. 98.) The courses planned for the group are as follows:

	Hours	
	1st Term	*2nd Term*
Heat-Power Engineering 3P41, 3P42	3	3
Mechanical Laboratory 3X41, 3X42	4	4
Electrical Laboratory 435, 436	2	2
Heat Engineering 3P57, 3P58	4	4
Refrigeration 3P49	2	0
Non-resident Lectures 3G41	0	1
Electives	4	5
Total number of hours each term	19	19

For suggested electives see list on page 87.

Group C

Industrial Engineering

This group is intended for those who wish to enter the commercial side of engineering or who are particularly interested in industrial organization and administration. In the special courses relating to this option the following topics are discussed: Modern time-keeping and cost-finding systems; methods of planning

work and insuring production; time and motion studies; purchasing; problems in administration, plant locating; heating; lighting; powering; safety engineering; fire protection and similar subjects. In the drafting and designing courses the graphical work includes the application of these fundamental principles to planning industrial enterprises. Students expecting to elect this option are advised to read for preparation as much industrial history and kindred subjects as possible.

	Hours	
	1st Term	*2nd Term*
Heat-Power Engineering 3P41, 3P42	3	3
Mechanical Laboratory 3X41, 3X42	4	4
Electrical Laboratory 435, 436	2	2
Heating, Ventilating, and Refrigeration 3X44	3 or 0	0 or 3
Industrial Engineering Lecture 3I42	0	1
Industrial Engineering Problems 3I43, 3I44	2	2
Industrial Relations 3I46	2	0
Cost Accounting 3I47	0	2
Industrial Engineering 3I48	0	2
Non-resident Lectures 3G41	0	1
Electives	3 or 5	2 or 0
Total number of hours each term	19 or 18	19 or 20

For suggested electives, see list on page 87.

Group D

Automotive Engineering

The wide variety of theoretical and practical problems arising in automotive design and operation, and the great industrial importance of this field of engineering, make the analysis of automotive machinery one of the most interesting of ways to introduce a student to engineering work. The "Automotive group" for seniors makes a study of the fundamentals of construction and operation of automotive vehicles. First term work studies the vehicle as a whole, the functions of steering, driving, braking; load distributions, framing, body design; and makes detailed analysis of power required for operation. Second term work studies power plant theory, design and operation. Two lectures are given a week, and two computing periods; the latter may also be used for drawing, or for laboratory work or demonstration.

	Hours	
	1st Term	*2nd Term*
Heat-Power Engineering 3P41, 3P42	3	3
Mechanical Laboratory 3X41, 3X42	4	4
Electrical Laboratory 435, 436	2	2
Heating, Ventilating, and Refrigeration 3X44	3 or 0	0 or 3
Motor Car Construction Lectures 3X45, 3X46	2	2
Motor Car Construction Computations 3X47, 3X48	2	2
Non-resident Lectures 3G41	0	1
Electives	3 or 6	5 or 2
Total number of hours each term	19	19

For suggested electives, see list on page 87.

Group E

Aeronautical Engineering

Students who are interested in aeronautical work may find a limited amount of specialization in aeronautics desirable in the senior year. For this option, the student must have elected an introductory course in aerodynamics in the junior year, and should preferably have had some instruction in practical flying. Flight train-

ELECTIVE SUBJECTS IN OTHER SCHOOLS AND COLLEGES—*Continued*

	Hours 1st Term	2nd Term
Illumination 466	0	2
Elementary Differential Equations 41	0 or 3	3 or 0
Patents 488	1	0
Advanced Calculus 42	3	3
Introductory Qualitative Analysis 210	0 or 3	3 or 0
Introductory Quantitative Analysis 225	0 or 3	3 or 0
Introductory Physical Chemistry (Lect.) 405	3	3
Introductory Physical Chemistry (Lab.) 410	3	3
Introductory Chem. Microscopy (Lect. & Lab.) 530	0 or 3	3 or 0
Metallography 545	2	0
Gas and Fuel Analysis 250	0 or 4	4 or 0
Physics courses dependent upon prerequisites (Consult the Department)		
Introductory Geology 100	3 or 0	0 or 3
Engineering Geology 501	4 or 0	0 or 4
Money and Banking 11	3 or 0	0 or 3
Industrial Hygiene 5	1	0
Public Speaking 1a	3 or 0	0 or 3

For other subjects such as Languages, History, Philosophy, Psychology, Government, Astronomy, Biology, Botany, Archaeology, Music, see announcements of the colleges concerned.

2. A FIVE-YEAR COURSE LEADING TO THE DEGREE OF M.E.

The requirements for admission to this course are the same as those for the four-year course, and the work of the first two years is the same. Without detailing the liberal arts electives, the rest of the course is tentatively as follows. Minor changes can be made after personal conference with the director of the school.

	Hours 1st Term	2nd Term
III		
Heat-Power Engineering 3P31, 3P32	3	3
Mechanical Laboratory 3X31, 3X32	4	3
Machine Design, Recitations 3D31, 3D32	2	2
Machine Design, Drawing 3D33	0	3
Machine Shop 3S31	0	3
Accounting 3A31	3	0
Electives	6	5
Total number of hours each term	18	19
IV		
Electrical Engineering 415, 416	3	3
Industrial Organization 3I31	2	0
Mechanical Laboratory 3X41, 3X42	4	4
Heat-Power Engineering 3P41, 3P42	3	3
Electives	6	8
Total number of hours each term	18	18
V		
Group Lectures	2	2
Group Design	2	2
Electrical Engineering 435, 436	2	2
Heating, Ventilating and Refrigeration 3X44	3 or 0	0 or 3
Non-resident Lectures 3G41	0	1
Electives	10 or 13	12 or 9
Total number of hours each term	19	19

3. A Five-Year Course Leading to the Degree of B.Chem. and Chemical Engineer

The requirements for admission to this course are those set by the College of Arts and Sciences for admission to the degree of B. Chem. The student registers for four years in that college, and upon the completion of the work outlined below for the first four years, receives the degree of B.Chem. The fifth year is taken under the joint control of the Department of Chemistry in the College of Arts and Sciences and of the Sibley School of Mechanical Engineering. The degree of Chemical Engineer is conferred upon the successful completion of the entire course.

For description of the courses in engineering, see the pages following; for description of the courses in Chemistry consult the Announcement of the Department of Chemistry.

FIRST YEAR

		Hours	
		1st Term	*2nd Term*
Introductory Inorganic Chemistry	Chem. 110	3	2
Inorganic Chemistry Laboratory	Chem. 115	3	0
Introductory Qualitative Analysis	Chem. 203	0	5
Analytic Geometry, Calculus	Math. 5a, 5b	5	5
Introductory Experimental Physics	Physics 11, 12	4	4
English	English 1	3	3
Total number of hours each term		18	19

SECOND YEAR

Introductory Organic Chemistry	Chem. 305	3	3
Organic Chemistry Laboratory	Chem. 310	3	3
Introductory Quantitative Analysis	Chem. 220	3	0
Quantitative Analysis Laboratory	Chem. 221	3	0
Gas and Fuel Analysis	Chem. 250	0	3
General Physics	Physics 21, 22	3	3
Drawing 125		0	3
German 1a		3	3
Total number of hours each term		18	18

THIRD YEAR

Introductory Physical Chemistry	Chem. 405	3	3
Physical Chemistry Laboratory	Chem. 410	3	3
Introductory Chemical Spectroscopy	Chem. 505	0	3
Advanced Quantitative Analysis	Chem. 230	3	0
Mechanics 3M21		5	0
Strength of Materials 3M22		0	3
Hydraulics 3M23		0	2
Materials of Engineering 3X21, 3X22		3	3
Total number of hours each term		17	17

FOURTH YEAR

		Hours 1st Term	Hours 2nd Term
Introductory Industrial Chemistry	Chem. 705	3	3
Advanced Inorganic Chemistry	Chem. 130	3	3
Special Topics in Physical Chemistry	Chem. 420	3	0
Introductory Chemical Microscopy	Chem. 530	0	3
Special Topics in Chemistry	Chem. 910	0	1
Elementary Mineralogy	Geology 311	3	0
Heat-Power Engineering, 3P33, 3P34		3	3
Mechanical Laboratory, 3X33, 3X32		3	3
Total number of hours each term		18	16

FIFTH YEAR

Electrical Engineering 405, 406		4	4
Mechanical Engineering Laboratory 3X43		2	0
Chemical Engineering Laboratory	Chem. 710	0	4
Machine Design, Recitations 3D34		2	0
Machine Design, Drawing 3D36		1	0
Chemical Plant Design	Chem. 730	3	3
Industrial Organization 3I31		2	0
Introduction to Economics	Economics 3	0	3
Electives		3	3
Total number of hours each term		17	17

4. A Six-Year Course Leading to the Degrees of A.B. and M.E.

The requirements for admission to this course are those of the College of Arts and Sciences, in which the student is registered for the first four years. The student must complete the freshman engineering subjects before beginning his fourth year, and he must complete the sophomore subjects in Mechanical Engineering before beginning his fifth year. Advice and assistance in arranging the six-year course may be obtained by applying to the Director of the Sibley School of Mechanical Engineering and to the Dean of the College of Arts and Sciences.

5. A Four-Year Course in Administrative Engineering Leading to the Degree of B.S. in A.E. With Special Reference to Mechanical Engineering

The requirements for admission to this Course are the same as for the regular four-year M.E. Course, see page 38.

It is possible so to arrange the work of a five-year course that the M.E. degree may be obtained at the end of the first four years and the B.S. in A.E. degree at the end of the fifth year. Declaration of intention to take the five-year M.E.-A.E. curriculum should be made at the beginning of the second year.

FRESHMAN YEAR

	Hours 1st Term	Hours 2nd Term
Mathematics 5a, 5b	5	5
Physics 11, 12	4	4
Chemistry 106 a, b	3	3
Descriptive Geometry and Drawing 120, 121	3	3
Surveying 111	2 or 0	0 or 2
Wood Shop 102	0 or 1	1 or 0
Engineering Laboratory 103	0 or 1	1 or 0
Introductory Lectures 130	1	0
Hygiene 1, 2	1	1
Total number of hours each term	19	18

In addition to taking the courses named in the above schedule, all freshmen must satisfy the University's requirement of three actual hours a week throughout the year in Military Science and Tactics (or in Physical Training; see the General Information Number).

SOPHOMORE YEAR

	Hours 1st Term	Hours 2nd Term
Mechanics 3M21	5	0
Strength of Materials 3M22	0	3
Hydraulics 3M23	0	2
Kinematics, Recitations 3D25	3	0
Empirical and Kinematic Drawing 3D26	2	0
Materials of Engineering 3X21, 3X22	2	0
Pattern Shop 3S21	0	1
Foundry 3S22	1	0
Machine Shop 3S32	0	2
English 21	3	0
Technical Writing 3A33	0	2
Economic Organization 3A21, 3A22	3	2
Business and Industrial Management 3A23	0	4
Total number of hours each term	20	19

In addition to taking the courses in the above schedule, all sophomores must satisfy the University's requirement of three actual hours a week throughout the year in Military Science and Tactics (or Physical Training; see the General Information Number).

JUNIOR YEAR

	Hours 1st Term	Hours 2nd Term
Heat-Power 3P33, 3P34	3	3
Machine Design, Recitations 3D34	2	0
Machine Design, Drawing 3D35	0	2
Mechanical Laboratory 3X33, 3X32	3	3
Electrical Engineering 405, 406	4	4
Accounting 3A31, 3A32	3	3
Business Statistics and Forecasts 3A41	0 or 3	3 or 0
Money and Banking, Economics 11	3 or 0	0 or 3
Total number of hours each term	18	18

SENIOR YEAR

	Hours 1st Term	2nd Term
Industrial Engineering Lectures 3I42	0	1
Industrial Engineering Problems 3I43, 3I44	2	2
Industrial Relations 3I46	2	0
Cost Accounting 3I47	0	2
Corporation Finance 3A34	0	3
Engineering Business Law 3A43, 3A46	3	3
Industrial Marketing 3A44	3	0
Public Speaking 1	3 or 0	0 or 3
Mechanical Laboratory 3X41, 3X42	4	4
Non-resident Lectures 3G41	0	1
Electives	2 or 5	3 or 0
Total number of hours each term	19	19

DESCRIPTION OF COURSES

For Freshmen

A description of the course of instruction for freshmen is given under the head The Freshman Year, beginning on page 48.

For Sophomores, Juniors, and Seniors

The following courses in Physics and English, are given in the College of Arts and Sciences. The rest are given in the College of Engineering.

For information about examinations for the removal of conditions in Mathematics, or Physics, students are referred to the Announcement of the College of Arts and Sciences or told to inquire of the department in which the examination is given.

PHYSICS

21. **General Physics.** Required of candidates for the degree of M.E. or E.E. First term. Credit three hours. Prerequisites, Physics 11 and 12 and Mathematics 5a and 5b. Two class-room periods a week and one laboratory period on alternate weeks. Laboratory work covering selected topics in electricity and magnetism. Assistant Professors Grantham and Collins and instructors.

22. **General Physics.** Required of candidates for the degree of M.E. or E.E. Second term. Credit three hours. Prerequisites, Physics 11 and 12 and Mathematics 5a and 5b. Physics 21 desirable, but not required. Two class-room periods a week and one laboratory period on alternate weeks. Theory, problems and laboratory work covering such selected topics as thermionics, photoelectricity, photometry, kinetic theory, radiation, polarized light, and diffraction. Assistant Professors Grantham and Collins and instructors.

ELECTRICAL ENGINEERING

Courses 415, 416, 435, 436, are required of all candidates for the M.E. degree. For a description of these courses, see pages 110-113 of this Announcement.

MACHINE CONSTRUCTION

(For courses in Wood Working and Introductory Engineering Laboratory, see Courses 102 and 103 under courses offered to freshmen, page 50.)

3S22. **Foundry Work.** Required of M.E. and A.E. sophomores. Either term. Credit two hours. Two two and one-half hour periods a week. Moulding, core making, mixing, and casting of metals; use of moulding machines. Demonstrations of large work and production in quantities. Mr. Patterson.

3S21. **Pattern Making.** Required of M.E. and A.E. sophomores. One hour either term as assigned. Pattern making: the use of hand and machine tools, followed by instruction in pattern making, construction of core boxes, etc.; demonstration of form turning. Messrs. BUSH and YAWGER. *Rand Hall, Third Floor.*

3S31. **Machine Work.** Required of M.E. juniors. Credit three hours one term. Nine hours of work a week. Prerequisite courses 102, 103, 3S22, and 3S21. Use of measuring instruments, hand and machine tools, fitting, and assembling; operation and use of jigs and other manufacturing fixtures; operation of semi-automatic and automatic machines, and the illustration of manufacturing methods generally. Professor WELLS, Messrs. HOWE and SCHALLOWITZ.

3S32. **Machine Work.** Required of A.E. and E.E. sophomores. Prerequisites 102 and 103. Credit two hours one term. Six hours of work a week. Use of measuring instruments, hand and machine tools, fitting, and assembling; operation and use of jigs and other manufacturing fixtures; operation of semi-automatic and automatic machines, and the illustration of manufacturing methods generally. Professor WELLS, Messrs. HOWE and SCHALLOWITZ.

DRAWING

(For the course in Descriptive Geometry and Engineering Drawing, see Courses 120 and 121 under courses offered to freshmen, page 49.)

125. **Drawing.** This course is given in the College of Engineering, but is designed only for students registered as candidates for the degrees of Bachelor of Chemistry and of Chemical Engineer. First term. Credit three hours. One recitation and two two and one-half hour drawing periods a week. Lettering, machine sketching, working drawings including conventions, tracing, isometric projection, etc. Professor TOWNSEND and instructors. *East Sibley.*

MACHINE DESIGN

3D21. **Kinematics Recitations.** Sophomores in Mechanical Engineering. First term. Credit two hours. Prerequisite courses 120 and 121 and Mathematics 5a and 5b. Two recitations a week throughout the term on the theory of motion; the transmission of motion; the instant center method of determining linear and angular velocities; vector method of determining linear and angular velocities and accelerations; cams; rolling curves and friction gearing; etc. Professors ALBERT and ROGERS and Messrs. MORRIS, KNIGHT, and TERRY.

3D23. **Empirical and Kinematic Drawing.** Sophomores in Mechanical Engineering. First term. Credit two hours. Must be taken with course 3D21. Prerequisite courses 120 and 121 and Mathematics 5a and 5b. Two drawing periods a week throughout the term, about twelve periods being devoted to empirical design and the remaining eighteen to drawing board applications of the theory and principles of course 3D21. Professors ALBERT and ROGERS and Messrs. MORRIS, KNIGHT, and TERRY.

3D24. **Kinematics, Recitations, and Drawing.** Sophomores in Mechanical Engineering. Second term. Credit three hours. Prerequisite course 3D21. About twenty-five recitation periods and twenty drawing periods, for which two recitation and two drawing periods a week must be provided in the student's schedule. Recitation and drawing board work dealing with gears; gear cutting; linkwork and miscellaneous mechanisms; belt, rope, and chain drives; and trains of mechanism. Professors ALBERT and ROGERS and Messrs. MORRIS, KNIGHT, and TERRY.

3D25. **Kinematics, Recitations.** Sophomores in Electrical and Administrative Engineering. First term. (Make-up section, second term). Credit three hours. Prerequisite courses 120 and 121 and Mathematics 5a and 5b. Three recitations a week throughout the term on the theory of motion; the transmission of motion; the instant center method of determining linear and angular velocities; cams; rolling curves and friction gearing; gears; gear cutting; linkwork and miscellaneous

mechanisms; belt, rope, and chain drives; and trains of mechanism. Professors ALBERT and ROGERS and Messrs. MORRIS, KNIGHT, and TERRY.

3D26. **Empirical and Kinematic Drawing.** Sophomores in Electrical and Administrative Engineering. First term. Credit two hours. Must be taken with course 3D25. Prerequisite courses 120 and 121 and Mathematics 5a and 5b. Two drawing periods a week throughout the term, about eight periods being devoted to empirical design and the remaining twenty-two to drawing board applications of the theory and principles of course 3D25. Professors ALBERT and ROGERS and Messrs. MORRIS, KNIGHT, and TERRY.

3D31. **Machine Design, Recitations.** Juniors in Mechanical Engineering. First term. Credit two hours. Prerequisite courses 3D21, 3D23, 3D24, 3X21, 3X22, 3M21 and 3M22. Two recitations a week throughout the term on the theoretical and practical applications of kinematics, materials, mechanics, and technology to the design of machines and machine elements with due regard to such considerations as suitability of materials, safety, lubrication, construction, etc. Professor ALBERT and Assistant Professor GARNER.

3D32. **Machine Design, Recitations.** Juniors in Mechanical Engineering. Second term. Credit two hours. Prerequisite course 3D31. Two recitations a week throughout the term on the theoretical and practical applications of kinematics, materials, mechanics, and technology to the design of machines and machine elements with due regard to such considerations as suitability of materials, safety, lubrication, construction, etc. Professor ALBERT, Assistant Professor GARNER, and Messrs. TERRY, MORRIS, and KNIGHT.

3D33. **Machine Design, Drawing.** Juniors in Mechanical Engineering. Second term. Credit three hours. Must be taken with course 3D32. Prerequisite course 3D31. Three drawing periods a week throughout the term. The student for the first time undertakes the design of a complete machine and makes all the necessary calculations and drawings. Orderly, systematic calculations are insisted upon and such layout and detail drawings are made as are found necessary to complete an assembly drawing of the machine. The last third of the term is devoted to a dynamical problem. Professor ALBERT, Assistant Professor GARNER, and Messrs. TERRY, MORRIS, and KNIGHT.

3D34. **Machine Design, Recitations.** Juniors in Electrical and Administrative Engineering and Seniors in Chemical Engineering. First term (Make-up section, second term.) Credit two hours. Prerequisite courses 3D25, 3D26, 3X21, 3X22, 3M21, and 3M22 for Electrical and Administrative Engineers and 125, 3X21, 3X22, 3M21, and 3M22 for Chemical Engineers. Two recitations a week throughout the term on the theoretical and practical applications of kinematics, materials, mechanics, and technology to the design of machines and machine elements with due regard to such considerations as lubrication, safety, suitability of materials, construction, etc. Professor ALBERT and Assistant Professor GARNER.

3D35. **Machine Design, Drawing.** Given the second term to Junior Electrical and to Junior Administrative Engineers. Credit two hours. Must be taken with course 3D34 or in the term following. Prerequisite courses 3D25, 3D26, 3X21, 3X22, 3M21, and 3M22. Two drawing periods a week throughout the term. The student for the first time undertakes the design of a complete machine and makes all the necessary calculations and drawings. Orderly systematic calculations are insisted upon, and such layout and detail drawings are made as are found necessary to complete an assembly drawing of the machine. Professor ALBERT, Assistant Professor GARNER, and Messrs. TERRY, MORRIS, and KNIGHT.

3D36. **Machine Design, Drawing.** Seniors in Chemical Engineering. Second term. Credit one hour. Prerequisite courses 125, 3X21, 3X22, 3M21, 3M22, and 3D34. One three-hour drawing period a week throughout the term. The work of the term includes a problem illustrative of the design of pressure vessels and the design of a single-cylinder, plunger pump fitted with a flywheel. Orderly systematic calculations are insisted upon, and such layout and detail drawings are made as are found necessary to complete an assembly drawing of the pump. Professor ALBERT or Assistant Professor GARNER.

3D51. **Mechanical Technology as Related to Design.** An elective for sophomores and juniors in engineering. Second term. Credit three hours. Three one hour periods a week; thirty-five recitation and discussion periods, six lectures, and four written examinations a term. The purpose of the course is to show how the various mechanical processes are related to design and production. The course is based on textbooks, dealing principally with measuring and the processes of fashioning metals by machining, cutting, grinding, shearing, punching, drawing, rolling, hammering, pressing, moulding, etc. Each period is devoted to an oral quiz and informal discussion of the day's assignment, with occasional lectures on the general and particular relations of mechanical processes to design work. Professor ALBERT.

3D52. **Advanced Kinematics and Kinetics.** An elective for juniors, seniors, and graduates. Second term. Credit three hours. Prerequisite courses 3D21, 3D23, and 3D24, or 3D25 and 3D26. About twenty-four lecture and discussion periods and about twenty-one three-hour drawing periods during the term, for which two one-hour and two three-hour periods a week must be provided in the student's schedule. Graphical and semi-graphical treatment of linear and angular velocities and accelerations and of the resulting forces, stresses, and strains due to the form and mass of the moving parts of mechanisms and machines. Vibration and critical speeds and the theoretical basis and use of balancing machines for securing static and running balance of machine parts will be treated so far as time permits. Professor ALBERT or Professor ROGERS.

3D53. **Materials Handling.** An elective for juniors, seniors, and graduates. Second term. Credit two hours. Prerequisite courses 3D21, 3D22, and 3D24, or 3D25 and 3D26. Two lectures a week throughout the term. Treatment and analysis of the known methods of handling different kinds of materials and of the principles and considerations involved in a proper choice of the method of handling any given kind of material. Professor————.

AUTOMOTIVE ENGINEERING

3X45, 3X46. **Motor Car Construction.** Credit two hours each term. Two lectures a week, illustrated. Two preliminary examinations, term problem, and a final examination. Either term's lectures may be used as a senior elective. First term work deals with design of chassis and body, and power requirements for operation; second term deals with power plant design and operation. Professor UPTON.

3X47, 3X48. **Motor Car Construction.** Drawing room, computing, or laboratory work paralleling the lecture courses 3X45, 3X46. Two preliminary examinations and a final examination. Professor UPTON.

MECHANICS OF ENGINEERING

3M21. **Theoretical and Applied Mechanics.** Sophomores. First term. Credit five hours. Four recitations and one examination a week. Prerequisite courses, Mathematics 5a and 5b. Motion of a Particle: displacement, velocity, acceleration; graphs; force, mass, and acceleration; equations of motion; curvilinear and rectilinear motion; rotation about an axis; moments. Systems of Particles: external and internal forces; general equations of motion; parallel forces; center of gravity. Statics: single pieces, cords, pulleys, structures and mechanisms. Motion of a Rigid Body: translation; rotation, moment of inertia of solids; plane motion. Work and energy: friction, brakes, dynamometers; power, efficiency, and regulation of machines. Professors WOOD and CORNELL, Assistant Professors PERKINS and WOOD.

3M22. **Strength of Materials.** Sophomores. Second term. Credit three hours. Nine weeks of second term. Four recitations and one examination a week. Prerequisite course 3M21. Stress, strain; strength and elastic properties of materials in tension, compression and shearing; riveted joints; torsion of shafts; helical springs; shear, moment, safe loading and deflection of simple beams; special beams; eccentric loads; columns; impact loads. Professors WOOD and CORNELL, Assistant Professors PERKINS and WOOD.

3M23. **Hydraulics.** Sophomores. Six weeks of second term. Four recitations and one examination a week. Credit two hours. Prerequisite course 3M21. Hydrostatics: pressures and centers of pressure. Hydrokinetics: general equations of energy; orifices, weirs, nozzles, Venturi meters, etc.; losses of head; flow in pipes. Hydrodynamics: forces on stationary and moving bodies. Professors WOOD and CORNELL, Assistant Professors PERKINS and WOOD.

3M24. **Engineering Mathematics.** Sophomores in Mechanical Engineering. Second term. Credit two hours. Two recitations a week. Prerequisite course 3M21. First and second order differential equations; curve plotting, choice of coordinates and scale, straight line plotting of simple equations; logarithmic plotting; fitting empirical equations to experimental data by methods of least squares and moments. Professor SWITZER and Assistant Professor PERKINS.

3M31. **Advanced Mechanics.** Juniors in Mechanical Engineering. First term. Credit three hours. Two recitations and one lecture a week. Prerequisite courses 3M21, 3M22 and 3M24. Continuous beams; combined stresses; principal stresses; Mohr's circle; theories of failure; thick walled cylinders; curved bars; unsymmetrical bending; linear, torsional and flexural vibrations, without and with damping; forced vibrations; balance of rigid rotors. Professor SWITZER and Assistant Professor PERKINS.

3M53. **Ordnance Problems.** Two lectures a week throughout the year. To be taken for two years. Credit one hour each term. Prerequisite courses 3M21 and 3M22. Captain DAVIS.

3M55. **Photo-elasticity.** Elective for seniors and graduates. Second term. Credit three hours. Two lectures and one laboratory period with report a week. Prerequisite course 3M31. Optics of photo-elasticity; plane and circularly polarized light, monochromatic and white light, fringes, isochromatics and isoclinics; discussion of models, materials and preparation. Elements of elasticity, including equilibrium and compatibility equations for plane stress, and stress functions; methods for determining principal stresses from photo-elastic observations and computations, isopachics. In the laboratory, experiments on the calibration of color and fringe scales by tension, compression, and bending, are followed by tests on centrally loaded beams, and the determination of stress concentration factors. Professor SWITZER.

AERONAUTICAL ENGINEERING

3M35. **Aerodynamics.** Second term. (Given first term, 1935-36.) Credit two hours. Prerequisite courses 3M21 and 3M22. Two recitations a week. Principles of flight, airplane performance and stability calculations. Assistant Professor WOOD.

3M36. **Airplane Design.** First term. Credit two hours. Prerequisite course 3M35. Two recitations a week. Weight and balance analysis, elements of stress analysis, layout principles. Term problem on preliminary design for an airplane. Assistant Professor WOOD.

3M45, 3M46. **Airplane Design.** Throughout the year. Credit two hours each term. Prerequisite course 3M35. Course 3M36 must accompany or precede course 3M45. Two drawing periods a week. The student makes calculations and drawings similar to those required by the Department of Commerce for approval of the design of an airplane. Factory and airport inspection trips. Assistant Professor WOOD.

3M51. **Aeronautic Problems.** Elective for seniors and graduates. Either term. Credit two to five hours as arranged. Prerequisite course 3M35 or its equivalent. Preparation of report on investigation of some specialized phase of aerodynamics such as airfoil characteristics, propeller characteristics, airplane performance, airplane stability, load factors for design, autogyro performance, rocket propulsion, or fluid resistance. Assistant Professor WOOD.

WATER-POWER ENGINEERING

3M41, 3M42. **Hydraulic Power Plants.** Lectures throughout the year. Credit two hours each term. Prerequisite courses 3M21, 3M22, and 3M23. Power Development: description, design, and cost of reservoirs, dams, headworks, water conduits, surge chambers, power house, tail race, construction plant. Hydraulic Turbines: construction, installation, operating characteristics including effects of water hammer in long pipe lines and variable head, selection of equipment, testing, governing, and speed regulation. Power Study: market for power, competition and rates, hydrology, head, economics of pondage and storage, power available and usable within the load curve, economy of auxiliary power. Water power legislation and the Federal Power Commission. During the entire course considerable emphasis is placed upon the financial problems of construction and operation of the water power plant alone and as part of a large power system. Some time is devoted to elementary concrete design and foundations. Professor SWITZER.

3M43, 3M44. **Hydraulic Power Plant Problems.** Computation periods throughout the year. Credit two hours each term. Must be accompanied by course 3M41, 3M42. Problems are assigned involving the principles taken up in course 3M41, 3M42. Design problems are given to show the applications of the fundamental principles of mechanics, machine design, and hydraulics, to the solution of problems in the water power field. The characteristics of hydraulic turbines are studied through the use of experimental data on turbine performance, and these results are applied to specific problems in power plant practice. Problems in stream flow, pondage and storage, power available and its use under specified load conditions conclude the work. Professor SWITZER.

3M52. **Special Hydraulic Power Plant Problem.** Elective for seniors and graduates. Either term. Credit two to five hours as arranged. Must be preceded by or taken with 3M41, 3M42. Selected topics from course 3M43, 3M44 and other special problems to meet the individual needs of each student. Students who have completed course 3M43, 3M44 or equivalent, may elect this course for more advanced work. Professor SWITZER.

HEAT-POWER ENGINEERING

3P31, 3P32. **Heat-Power Engineering.** Required of all juniors in Mechanical Engineering. Throughout the year. Credit three hours a term. Prerequisite courses, Physics 21 and 22 and 3D21, 3D23, 3D24, 3M21, 3M22. Two recitations and one lecture a week throughout the year. Thermodynamics of gases and vapors; ideal cycles and their application in air compressors, internal combustion motors, steam engines, turbines and power plants; modifications in actual machines; efficiencies and performances; study of engine losses and the usual means of reducing them; compound, uniflow, and other types of steam engines; types of air compressors, internal combustion engines. On account of the importance of a thorough understanding of this subject, the student is required to solve a large number of problems in the classroom. Assistant Professor MACKEY.

3P33, 3P34. **Heat-Power Engineering.** Required of juniors in Electrical Engineering and in Administrative Engineering. Not open to students in Mechanical Engineering. Throughout the year. Credit three hours a term. One lecture and two recitations a week. Prerequisite courses, Physics 21 and 22 and 3D25, 3D26, 3M21, 3M22. The course is an abridged treatment of substantially the same ground as courses 3P31, 3P32, and 3P41, 3P42. The longer courses 3P31, 3P32, and 3P41, 3P42 may be substituted for this one. Assistant Professor HOOK.

3P41, 3P42. **Heat-Power Engineering.** Required of all seniors in Mechanical Engineering. Throughout the year. Credit three hours a term. Prerequisite course 3P31, 3P32. Three recitations a week. An extension of course 3P31, 3P32. Governors; engine and turbine types; steam turbine theory, development of present forms, performance, economy, suitability for particular service; fuels and fuel resources; combustion, ideal and in the actual furnace and engine; steam gen-

erating units and their performance; furnaces, boilers, superheaters, economizers, and air preheaters; exit losses; draft; heat transfer; flow in pipes; feed water heaters, condensers, cooling towers and other apparatus; feed water treatment; consideration of the economical combination of elements in plants. Refrigeration. Professor ELLENWOOD and Assistant Professor CLARK.

3P43. **Heat-Power Engineering.** Required of seniors in Civil Engineering. Either term. Credit three hours. Two lectures and one two-hour laboratory or computing period a week. Not open to students in Mechanical or Electrical Engineering. Prerequisite courses, Physics 11 and 12 (or the equivalent), Chemistry 101 and 105, C.E. 220 and 221. One lecture and two recitations a week. Elementary consideration of behavior of gases and vapors as applied to heat engines; study of air compressors, internal combustion motors, steam boilers, engines, turbines and condensers; contractors' plants; cost of energy; and similar topics. This course is recommended for all students who wish to obtain a general basic knowledge of Heat-Power Engineering without great technical detail. Professor ELLENWOOD.

3P44, 3P45. **Steam-Power Plants.** Lectures throughout the year. Credit two hours a term. Prerequisite courses 3D31, 3D32, 3D33, and 3P31, 3P32; must be accompanied or preceded by courses 3P41 and 3P42. Load curves; station factors; power-plant economics; cost of plants and of their equipment and output; principles of economic selection of plant equipment with respect to the load curve, cost factors and local conditions; steam prime movers, steam generators, condensers, and other plant apparatus; performance characteristics and design features of this apparatus; piping; coal and ash storage and conveying machinery; plant location; plant layout; and similar topics. Professor BARNARD.

3P46, 3P47. **Computing and Design.** Throughout the year. Credit two hours a term. Must be accompanied by 3P44, 3P45. Two three-hour periods a week. The practical solution of problems discussed in 3P44, 3P45. Professor BARNARD.

3P48 **Fluid Flow, Heat Transmission and Air Conditioning.** Elective. M.E. Seniors. First term. Credit two hours. Prerequisite course 3P32. Must be accompanied by course 3P41. Two lectures or recitations a week. Fluid dynamics, dimensional analysis, Reynolds' and other dimensionless numbers, flow through pipes and ducts and over tube bundles and extended surfaces. Review of general principles of heat transmission. Applications to air conditioning and industrial apparatus. Assistant Professor MACKEY.

3P49 **Refrigeration.** Elective. M.E., E.E., and A.E. seniors. Second term. Credit two hours. Prerequisite course 3P32 or 3P34. Two lectures or recitations a week. A course dealing with the general principles, applications, and economic and commercial factors involved in various forms of modern refrigeration as applied to both domestic and industrial installations, including those pertaining to air conditioning. Professor ELLENWOOD.

3P50. **Power Plant Economics.** Elective for seniors. Second term. Credit two hours. Prerequisite courses 3P31, 3P32 or 3P33, 3P34. Two lectures a week. Costs of equipment and plants, load curves, station factors, determining characteristics of equipment, selection of working pressures and temperatures and cycles, proper load distribution, economic number and size of units; selection of equipment based on these and other determining considerations; economic operation. Applications to central stations and to industrial power and heating plants. Cost of energy. Other similar topics. Professor BARNARD.

3P51. **Steam Turbines.** Elective for seniors. Second term. Credit two hours. Prerequisite courses 3P31, 3P32 or 3P33, 3P34. Two lectures a week. Classification of turbines and description of leading features of the various types; mechanical and thermal considerations underlying the action of steam in turbines; calculations involved in turbine design; discussion of building, erecting, and testing; adaptability to special conditions of service; economic results of the use of turbines in engineering practice. Assistant Professor CLARK.

3P52. **Internal Combustion Engines.** Elective. Seniors. First term. Credit two hours. Prerequisite courses 3D31, 3D32, 3D33 and 3P31, 3P32 or 3P33, 3P34. Two periods a week. Seminar. Reports and discussions. Fuels; general theory and salient points in the design and operation of internal combustion engines; study of existing commercial types, relative advantages, and questions of economy; current developments. Assistant Professor CLARK.

3P53. **Steam Boilers and Related Apparatus.** Elective. Seniors. First term. Credit two hours. Prerequisite courses 3D31, 3D32, 3D33, and 3P31, 3P32 or 3P33, 3P34. Two periods a week. Fuels, combustion, combustion apparatus; furnaces and boiler types, proportions, materials, design of details; superheaters, economizers, air heaters; accessories; equipment, arrangement and operation of steam generating plants. Professor BARNARD.

3P55. **Graphical Computation and Representation.** Elective. Second term. Credit two hours. Prerequisite courses 3D31, 3D32, 3D33, 3P31, 3P32 or 3P33, 3P34. Slide rules; construction of net work charts and alignment charts for the solution of equations; representation of statistics; and derivation of empirical equations from experimental curve. Assistant Professor MACKEY.

3P56. **Advanced Heat-Power Engineering Research.** Elective for graduate students and others qualified for study in this field. Work and credit as arranged with Professors BARNARD and ELLENWOOD.

3P57, 3P58. **Heat Engineering.** (Not given until the academic year 1936-37; in the meantime see courses 3P48 and 3P49). M.E. seniors. Throughout the year. Credit four hours a term. Must be accompanied by 3P41 and 3P42. Lectures, recitations and computing periods arranged as required. An expansion of course 3P48 (see description above).

EXPERIMENTAL ENGINEERING

The work in this department is given in two divisions: (A) Courses that are required of all students for graduation, and (B) research courses that are elective.

A. MECHANICAL LABORATORY

3X21, 3X22. **Manufacture and Properties of Engineering Materials.** Required of sophomores. Throughout the year. Credit three hours each term. Prerequisite courses Chemistry 106 a, b. Three lectures a week. Metallurgy of iron and steel, etc. Professor DIEDERICHS.

3X31. **Mechanical Laboratory—Properties of Engineering Materials.** M.E. Juniors. First term. Credit four hours. Prerequisite courses 3X21, 3X22, 3M21, 3M22. One laboratory period a week. Mechanical strength of materials; tension, torsion, transverse, and compression tests; the variation of the mechanical strength with differences in composition or heat treatment; demonstration of different methods of tempering, annealing, forging, etc. The student is required to write and submit one report each week upon the experiment of the previous week. Professor DAVIS and instructors.

3X32. **Mechanical Laboratory—Introductory Experimental Engineering.** M.E., E.E. & A.E. Juniors. Second term. Credit three hours. Prerequisite courses, Mechanics 3M21 and 3M22, Chemistry 106 a, b, Physics 21 and 22. One laboratory period a week as assigned; one written report a week. Calibration of indicator springs, steam guages, thermometers, and dynamometers; flue gas analysis and calculations; viscosity and friction tests of lubricants on various testing machines; tests of heating values of coals; steam quality tests, with various forms of calorimeters; tests of ignition and carburetion of gasoline engines, etc. Reports are required and must include all the data and results of the various tests, together with conclusions. The preparation of the report is considered an important part of the course. Professor DAVIS and instructors.

3X33. **Mechanical Laboratory—Properties of Engineering Materials.** E.E. and A.E. juniors. First term. Credit three hours. Contents practically as course 3X31.

3X41. **Mechanical Laboratory—Experimental Engineering.** For seniors in Mechanical Engineering and in Administrative Engineering in M.E. First term. Credit four hours. Prerequisite courses 3X32, 3P31, 3P32 and 3M23. One laboratory period a week. Efficiency tests of gas and gasoline engines, steam injectors, steam turbine, blowing fan, hydraulic turbine, and centrifugal pump. A written report is required for each experiment. Reports must be full and complete, and include data and results of each test, the testing methods used, the basic theory of the apparatus, and the performance results expressed numerically and graphically, with discussion. Professor GAGE, Assistant Professor ANDRAE, and instructors.

3X42. **Mechanical Laboratory—Experimental Engineering.** For seniors in Mechanical Engineering and in Administrative Engineering in M.E. Second term. Credit four hours. One laboratory period a week alternating with one computing period. A written report is required on each experiment. Detailed study of methods of testing and methods of computation in the following subjects: testing of engines and boilers, air compressors, ice machines; measurement of flow of water and air, etc. Reports required as in 3X41. Professor GAGE, Assistant Professor ANDRAE, and instructors.

3X43. **Mechanical Laboratory.** Required of seniors in Electrical Engineering and in Administrative Engineering in E.E. First term. Credit two hours. Prerequisite courses 3X32, 3P33, 3P34, 3M23. Selected experiments from Course 3X41. Professor GAGE, Assistant Professor ANDRAE, and instructors.

3X44. **Heating, Ventilating, and Refrigeration.** Required of seniors in Mechanical Engineering. Either term. Credit three hours. Lectures or recitations covering the methods of design and construction of various forms of heating and ventilating apparatus, and the principles of refrigeration. Professor SAWDON.

B. EXPERIMENTAL ENGINEERING RESEARCH

3X51. **Experimental Engineering Research.** Elective. Either or both terms. Credit one hour for forty hours of actual work. Open to a limited number of seniors and graduates who have available at least two laboratory periods a week and who have shown proficiency in engineering subjects. Special problems and investigations which are in general carried on in the laboratories under the immediate direction of the members of this department, but which may be carried on in any department of the College under the general supervision of this department. Professors DIEDERICHS, SAWDON, UPTON, GAGE, and DAVIS.

3X52. **Applied Metallography.** Elective. First term. Credit two hours. Prerequisite course 3X21, 3X22. Covers in historical sequence the development of knowledge of the internal structure of metals, and the relation of structure and properties; the technique of metallographic research, study of application of the laws of physical chemistry to interpretation and correlation of results. Study of stable and metastable conditions; heat treatment theory and practice. The practical aim of metallography is constantly emphasized. Professor UPTON.

INDUSTRIAL ENGINEERING

3I31. **Industrial Organization.** Required of all juniors in Mechanical and in Electrical Engineering. Either term. Credit two hours. Open only to upperclassmen except by special arrangement. A course of lectures on modern industrial tendencies and the principles that underlie modern methods of production. The treatment includes not only the reasons for our changed methods of production but also discussion of the principal features of such industrial factors as factory legislation, factory welfare work, and modern methods of administration. Professor KIMBALL.

3I42. **Industrial Engineering.** One lecture a week throughout the year. Credit one hour second term. This period is used for the purpose of lectures, frequently illustrated by slides or moving pictures, illustrating and explaining the work in courses 3I43 and 3I44, and for quizzes and preliminary examinations in

these courses. Must accompany 3I43 and 3I44. Professor LEE and Assistant Professor KIMBALL.

3I43, 3I44. **Industrial Engineering Problems.** Five hours of drawing, computing or time study a week throughout the year. Credit two hours each term. Must be accompanied by 3I42. Design and layout of a plant, including the selection and location of the machinery necessary to manufacture some small assembly such as an automobile transmission. A rather detailed solution of problems in costing, planning, routing, scheduling, etc., in connection with this plant, including the development of organization charts and administrative and other forms. The work also includes a detailed study of the use of the machine rate method of distributing overhead expense and a thorough practice in the making and using of time studies and rate tables. Professor LEE, Assistant Professor KIMBALL, and Mr. ROY.

3I46. **Industrial Relations.** Two lectures or recitations a week during either term. Credit two hours. Prerequisite course 3I31, or 3A23. A discussion of the more important problems which arise from the relation of employer and employee under present conditions of industry. Such features are considered as the effect of organized labor, employment methods, methods of wage payment, committee systems, industrial education and personnel service activities in general. Professor LEE and Assistant Professor KIMBALL.

3I47. **Cost Accounting.** Second term. Credit two hours. Required of all students in Administrative Engineering and of Mechanical Engineering seniors electing the Industrial Engineering option. One recitation or lecture and one two and one-half hour computing period. Prerequisite, course 3A31. A detailed study of manufacturing cost systems dealing with order costs, process costs, and standard costs. The latter portion of the term is devoted to a study of general economic considerations connected with the subject of costing, such as pricing policies, determination of "break even" point, advisability of attaining higher sales by selling below cost under certain conditions, etc. Professor LEE, Assistant Professor KIMBALL, and Mr. ROY.

3I48. **Industrial Engineering.** Two recitation and discussion periods a week during the second term. Credit two hours. Prerequisite courses 3I43, and 3A31 or its equivalent. A consideration of problems in industrial organization and administration including budgetary control, control of materials and production; and a study of the economic and human factors involved in manufacturing. The case method of presentation is frequently used. Professor LEE and Assistant Professor KIMBALL.

3I51. **Advanced Industrial Engineering.** Open to graduates and seniors who have completed the equivalent of 3I43 and 3I44. Professor LEE, Assistant Professor KIMBALL, and Mr. ROY.

ADMINISTRATIVE ENGINEERING

3A21. **Economic Organization.** Lectures, collateral reading, and discussion periods. First term. Credit three hours.

The origins and development of the arrangements by which specialization and coordination in economic affairs are brought about and the resulting product apportioned. The structure and working of our present system. Its faults. Possible remedies. Professor GARRETT.

3A22. **Economic Organization.** Lectures. Second term. Credit two hours. Continuation of the work of 3A21. Discussion of certain outstanding problems. Professor GARRETT.

3A23. **Business and Industrial Management.** Second term. Credit four hours. Required of all Sophomores in Administrative Engineering. Four lecture-discussion periods a week with regularly assigned problems. Prerequisite 3A21.

This course is intended as a survey of the problems of business and industrial organization. It deals with the establishment of business policies, types of business and industrial ownership, together with the functions of finance, control,

machine production, personnel and marketing. Elementary consideration will be given to the problems of the selection of plant site, time and motion study, wage systems and the selection of personnel, all of which will be developed in greater detail in subsequent courses. Professor BANGS.

3A31. **Accounting for Engineers.** Required of all A.E. and M.E. juniors. Given first term for A.E. and second term for M.E. juniors. Credit three hours. Two recitations and one 2½ hour computing period a week. Prerequisite courses 3A21 and 3A22 or their equivalent. Theory of debits and credits; development of books of original entry; voucher system; analysis of financial statements; financial mathematics; negotiable instruments; budgetary control; modern mechanical methods of performing the accounting function. Mr. MILLARD and others.

3A32. **Accounting for Engineers.** Second term. Required of all juniors in Administrative Engineering. Credit three hours. Two recitations and one 2½ hour computing period a week. Prerequisite course 3A31. Continues the work of first term 3A31, covering the extension of proprietorship; bond and stock issues and valuation; negotiable instruments; consolidations; mergers and holding companies; good will; depreciation; reserves; sinking funds; actuarial science; flexible budget; controversial accounting subjects; consolidated statements; statement analysis. Mr. HANSELMAN.

3A33. **Technical Writing.** First or second term as assigned. Two recitations a week. Credit two hours. Required of all sophomores in Administrative Engineering. A study of the forms of written expression with emphasis on those most frequently used in engineering and business. The writing of short reports, editorials, news articles, technical magazine articles, simple advertisements, and book reviews. Composition of business letters, such as credit, inquiry, quotation, order, collection, adjustment and sales letters, with examples of internal correspondence of a corporation. This course aims to give the student a knowledge of those practices in writing which will assist him in his work in the administrative phases of a manufacturing or technical enterprise. Professor BANGS and Mr. LOBERG.

3A34. **Corporation Finance.** Second term. Credit three hours. Required of all seniors in Administrative Engineering, elective for upperclassmen in Mechanical Engineering. Prerequisite courses 3A21, 3A22, and 3A31.

A study of the financial problems of the business corporation from the points of view of the management, the investor, and the public. Assistant Professor O'LEARY.

3A41. **Business Statistics and Forecasts.** First or second term. Three recitations a week. Credit three hours. Required of all juniors in Administrative Engineering. Prerequisite courses 3A21, 3A22.

Elements of the technique of statistical analysis. The collection, preparation, and use of business statistics. The sources of information. Business indices and business barometers. Professor GARRETT.

3A43, 3A46. **Engineering Business Law.** Throughout the year. Credit three hours a term. Required of all seniors in Administrative Engineering. A study of the fundamental legal principles which relate to the usual business transactions with emphasis on the laws of contracts, agency, negotiable instruments, sales, and corporations, and on employers' liability and workmen's compensation. By the use of adequate case material the student is aided in his application of the general legal principles to specific situations. Mr. HANSELMAN.

3A44. **Industrial Marketing.** First term. Required of all seniors in Administrative Engineering. Credit three hours. Two recitations and one lecture a week. Prerequisite courses 3A21, 3A22, 3A23, and 3A41. A study of the field of industrial marketing using the case method of instruction. The scope of the course includes product planning, policy, and research; sales and market analysis; distribution channels; pricing and terms of sale; sales promotion; management and organization of sales force; sales control. Professor BANGS and Mr. LOBERG.

3A45. **Industrial Marketing.** Elective. Second term. Credit two hours. One recitation and one 2½ hour laboratory period a week. Prerequisite course 3A44. The application of the principles of marketing to specific problems. Each student will develop a complete market study and analysis for given industrial products. Professor BANGS and Mr. LOBERG.

3A51. **Business and Industrial Research.** Elective. Either or both terms. Credit one hour for forty hours of actual work. Open to a very limited number of seniors and graduate students who have shown by training and aptitude their ability to carry on original investigations in business and industrial subjects. Professors BANGS and GARRETT, and Messrs. HANSELMAN, MILLARD, and LOBERG.

Econ. 11. **Money and Banking.** Either term. Credit three hours. Prerequisite courses 3A21, 3A22. Required of all juniors in Administrative Engineering.

A study of the history and theory of money and banking. Professor REED.

English 21. First or second term. Credit three hours a term. Required of all sophomores in Administrative Engineering. A course in composition with readings mainly from contemporary English and American literature. Professor R. P. SIBLEY. MWF 12.

GENERAL COURSES

3G52. **Sibley Journal Credit.** Undergraduate members of the *Sibley Journal* Board may receive not to exceed two hours of University credit in each term of their senior year (i.e. a maximum credit of four hours) for work satisfactorily done for *The Sibley Journal*, provided they are elected to the Board during or before their sophomore year, and continue active members to the end of the term in which credit is desired.

3G41. **Non-resident Lectures.** Required for graduation of all seniors in Mechanical and Administrative Engineering. These lectures are given at some hour in the day specially set aside in the senior schedules. Seniors may also be required to attend certain of the non-resident lectures given in E.E. 491. Notices of the lectures will be posted on the bulletin board of the Sibley School of Mechanical Engineering. A notebook showing a résumé of each lecture attended (not more than one page for each lecture) must be handed in at the Director's office during block week at the end of the second term.

3G51. **A.S.M.E., Student Branch.** Members of the junior and senior classes in Mechanical Engineering may obtain one hour elective credit in one, or both years, by joining the Student Branch of the American Society of Mechanical Engineers, and by attending all of the Branch Meetings during the year. Application for membership should be made at the Director's office in October of each year, or to Professor F. O. ELLENWOOD, Honorary Chairman of the Student Branch.

FRANKLIN HALL

The Main Building of the School of Electrical Engineering

The Senior Electrical Laboratory occupies the second floor of Rand Hall (See page 28).

SCHOOL OF ELECTRICAL ENGINEERING

OUTLINE OF THE INSTRUCTION

The regular four-year course in Electrical Engineering is planned to give the thorough grounding in electrical engineering required by engineers connected with the design, construction, and operation of the electrical part of engineering properties. The curriculum forms a balanced course of study along broad lines, and a moderate amount of special work is provided for by elective courses. A large proportion of the work in Mechanical Engineering is also taken by those who elect Electrical Engineering, so that the student is not limited in his outlook nor in his choice of work after graduation. For those desiring a still broader training, which shall include more of the liberal arts, a six-year course leading to the degrees of A.B. and E.E., is offered. (See page 108.)

The instruction in Mathematics, Physics, Chemistry, and English is given in the College of Arts and Sciences. All other subjects in the regular curriculum are given in the various departments of the Sibley School of Mechanical Engineering, the School of Civil Engineering, and the School of Electrical Engineering.

The instruction in the School of Electrical Engineering is distributed among the following departments: (1) Fundamental Elements, (2) Advanced Theory and Research, (3) Electrical Laboratories, (4) Electrical Design, (5) Electrical Communication, and (6) Electrical Transportation.

Instruction in Electrical Engineering begins in the sophomore year, and is based on the required courses in Physics and Mathematics. Emphasis is placed on the fundamental principles, and the subject is developed by elaborating these principles. Both direct and alternating current circuits and machinery are taken up. The theory is given in experimental lectures and in recitations, and is applied to short problems in the computing room. In the laboratory, the student handles machinery, selects his own instruments and control apparatus, and makes the necessary tests to check the theoretical work.

The principal part of the work for seniors in Electrical Engineering is given in a balanced course in which advanced theory, problem work, design, and laboratory practice are combined to give the student a broad training. The electrical laboratory, being flexible, lends itself particularly to the development of resourcefulness and initiative on the part of students. A moderate amount of special work is provided for by elective courses in electrical power stations, electrical design, electrical communication, electric traction, illumination, etc., in which the classes are small and more time is devoted to these subjects than is possible in the more general courses.

Instruction in Electrical Engineering is also provided for students in Chemistry, Civil Engineering, and Mechanical Engineering, and is adapted in each case to meet the respective requirements in those branches.

COURSES LEADING TO THE DEGREE OF ELECTRICAL ENGINEER

1. The Regular Four-Year Course

One hour of credit in the following schedules corresponds to about three hours of actual work a week for the term of fifteen weeks. Thus, from two and one-half to three hours a week of actual work in shop, laboratory, computing room, or drawing room count as one hour of credit, while each recitation hour assumes about two hours of outside preparation and counts as one hour of credit.

THE FRESHMAN YEAR

There is fundamentally a single schedule of studies prescribed for all students in the freshman year of the College of Engineering. That schedule is set forth in full under the head The Freshman Year, beginning on page 48.

THE SOPHOMORE YEAR

	Hours	
	1st Term	*2nd Term*
Mechanics 3M21	5	0
Strength of Materials 3M22	0	3
Hydraulics 3M23	0	2
Physics 21, 22	3	3
Kinematics, Recitations, 3D25	3	0
Empirical and Kinematic Drawing 3D26	2	0
Materials of Engineering 3X21, 3X22	3	3
Economic Organization 3A21, 3A22	3	2
Machine Shop 3S32	0	2
Electrical Engineering 410	0	4
Total number of hours each term	19	19

In addition to taking the courses named in the above schedule, all sophomores must satisfy the University's requirement of three hours a week throughout the year in Military Science and Tactics (or in Physical Training; see the General Information Number).

THE JUNIOR YEAR

	Hours	
	1st Term	*2nd Term*
Electrical Engineering 411a, 412a	5	3
Electrical Laboratory 431, 432	2	2
Heat-Power Engineering 3P33, 3P34	3	3
Mechanical Laboratory 3X33, 3X32	3	3
Machine Design, Recitations, 3D34	2	0
Machine Design, Drawing, 3D35	0	2
Industrial Organization 3I31	2	0
Mathematical Applications 420	0	3
English or Public Speaking	0	3
Elective	2	0
Total number of hours each term	19	19

THE SENIOR YEAR

	Hours 1st Term	2nd Term
Electrical Theory, Lectures, 421, 422	2	2
Electrical Theory, Recitations and Comp. 423, 424	3	3
Electrical Laboratory 433, 434	3	4
Central Stations 441	3	0
Medium and High Frequency Phenomena 451	3	0
Mechanical Laboratory 3X43	2	0
Non-resident Lectures 491	0	1
Electives*	3	9
Total number of hours each term	19	19

*Of the elective hours, at least four must be taken in an approved technical course during the second term of the senior year. The remainder of the elective hours may be taken in any department of the University, provided the student has the necessary preparation and the approval of his class adviser.

ELECTIVE COURSES OF STUDY

A student may elect any course of study offered by any department of the University, provided he have the necessary preparation for that course and the approval of his class adviser.

Not more than four hours credit in Advanced Military Science, in addition to the required military training of the freshman and sophomore years, will be accepted toward meeting the requirements for the E.E degree.

Following is a list of the technical electives to be given in the School of Electrical Engineering; they are for seniors and graduate students only:

Electrical Design 442	0	4
Electrical Communication Engineering 452	0	4
Elements of Electric Railway Practice 461	2	0
Industrial Applications and Control 462	0	2
Electrical Transmission and Distribution 464 (for E.E.)	0	3
Current Electrical Topics 471, 472	2	2
Engineering Mathematics 481, 482	2	2
Heaviside's Operational Analysis 486, 487	3	3
Patents 488	1	0
Current Topics in Communication Engineering 454	0	2
Special Electrical Engineering Problems 483, 484	1-3	1-3
Special and Non-resident Lectures, 491, throughout the year	0	1
The Economics of Public Utilities 444	0	2
A. I. E. E. 492	0	1

PHYSICS OPTION

For some time there has been a demand for a course in Electrical Engineering with a much broader training in Physics than is possible in the regular four-year course. While no rigid curriculum is given, an E.E. junior or senior with high scholastic grades in Mathematics, Physics, and Mechanics, and a satisfactory record in his other freshman and sophomore courses, may, with the approval of his class adviser, substitute for not more than the following required and optional courses a properly arranged sequence of Physics courses.

THE JUNIOR YEAR

	Hours 1st Term	2nd Term
Machine Design, Recitations 3D34	2	0
Machine Design, Drawing 3D35	0	2
Industrial Organization 3I31	2	0
English or Public Speaking	0	3
Electives	2	0
Total number of hours	6	5

THE SENIOR YEAR	Hours 1st Term	2nd Term
Central Stations 441	3	0
Mechanical Laboratory 3X43	2	0
Electives (technical and general)	3	9
Total number of hours	8	9

The permission to continue the Physics option may be withdrawn at any time should the student's scholastic standing in the optional Physics courses or in the required technical courses be not satisfactory.

2. A Six-Year Course Leading to the Degrees of A.B. and E.E.

The requirements for admission to this course are those of the College of Arts and Sciences, in which the student is registered for the first four years. The student must complete the freshman engineering subjects before beginning his fourth year, and he must complete the sophomore subjects in Electrical Engineering before beginning his fifth year. Advice and assistance in arranging the six-year course may be obtained by applying to the Director of the School of Electrical Engineering and to the Dean of the College of Arts and Sciences.

3. A Four-Year Course in Administrative Engineering Leading to the Degree of B.S. in A.E. With Special Reference to Electrical Engineering

The object of this course is given under the heading "Administrative Engineering" on page 81.

The course differs from that offered in Mechanical Engineering in that more stress is given to fundamental Electrical Engineering with special reference to the applications of Electrical Power and to Public Utility Engineering.

The requirements for admission are the same as for the regular four-year E.E. course, see page 38.

It is possible by an additional year of study to receive the Electrical Engineering degree, although it is highly desirable that if a student wishes both degrees he signify this intention at the beginning of the Sophomore Year.

FRESHMAN YEAR	Hours 1st Term	2nd Term
Mathematics 5a, 5b	5	5
Physics 11, 12	4	4
Chemistry 106 a, b	3	3
Descriptive Geometry and Drawing 120, 121	3	3
Surveying 111	2 or 0	0 or 2
Wood Shop 102	0 or 1	1 or 0
Engineering Laboratory 103	0 or 1	1 or 0
Introductory Lectures 130	1	0
Hygiene 1, 2	1	1
Total number of hours each term	19	18

In addition to taking the courses named in the above schedule, all freshmen must satisfy the University's requirement of three actual hours a week throughout the year in Military Science and Tactics (or in Physical Training; see the General Information Number).

SOPHOMORE YEAR

	Hours 1st Term	2nd Term
Mechanics 3M21	5	0
Strength of Materials 3M22	0	3
Hydraulics 3M23	0	2
Kinematics, Recitations 3D25	3	0
Empirical and Kinematic Drawing 3D26	2	0
Materials of Engineering 3X21, 3X22	3	3
Pattern Shop 3S21	0	1
Foundry 3S22	1	0
Machine Shop 3S32	0	2
English 21	3	0
Technical Writing 3A33	0	2
Economic Organization 3A21, 3A22	3	2
Business and Industrial Management 3A23	0	4
Total number of hours each term	20	19

In addition to taking the courses in the above schedule, all sophomores must satisfy the University's requirement of three actual hours a week throughout the year in Military Science and Tactics (or Physical Training; see the General Information Number).

JUNIOR YEAR

	Hours 1st Term	2nd Term
Heat-Power 3P33, 3P34	3	3
Machine Design, Recitations 3D34	2	0
Machine Design, Drawing, 3D35	0	2
Mechanical Laboratory 3X33, 3X32	3	3
Electrical Engineering 405, 406	4	4
Accounting 3A31, 3A32	3	3
Business Statistics and Forecasts 3A41	3 or 0	0 or 3
Money and Banking, Economics 11	0 or 3	3 or 0
Total number of hours each term	18	18

SENIOR YEAR

	Hours 1st Term	2nd Term
Industrial Engineering Lectures 3I48	0	1
Industrial Engineering Problems 3I43, 3I44	2	2
Industrial Relations 3I46	2	0
Cost Accounting 3I47	0	2
Corporation Finance 3A34	0	3
Engineering Business Law 3A43, 3A46	3	3
Industrial Marketing 3A44	3	0
Public Speaking 1	3 or 0	0 or 3
Mechanical Laboratory 3X43	2	0
Electrical Engineering 401, 402	3	3
Non-resident Lectures 491	0	1
Electives	2 or 5	3 or 0
Total number of hours each term	20	18

A LIST OF THE COURSES OF INSTRUCTION

For Freshmen

A description of the courses of instruction for freshmen is given under the head The Freshman Year, beginning on page 48.

For Sophomores

Description of courses given to sophomores in Electrical Engineering and to students in Administrative Engineering by the various departments of Mechanical Engineering as well as descriptions of courses in Physics and Chemistry common to both schools will be found in the list of courses of instruction of the Sibley School of Mechanical Engineering beginning on page 92.

For Juniors and Seniors

The courses in the following list are given in the School of Electrical Engineering. Information about other theoretical, electrical, and illumination courses will be found under Mathematics and Physics in the Announcement of the College of Arts and Sciences.

401. **Industrial Applications of Electrical Power.** Required of seniors in Administrative Engineering in Electrical Engineering. Three hours a week. First term only. A study of the principles underlying the economic application of electricity to industrial problems such as motor drives and control; electric heating and the use of electric furnaces and ovens; transportation and handling of materials; illumination and its effect on economic production. Professor Lincoln.

402. **The Economics of Public Utilities.** Required of seniors in Administrative Engineering in Electrical Engineering. Second term only. Three recitations a week. A study of the Origin and Development of Public Utilities, Franchises, Regulation and Legislation, Valuation, Rates and Rate Structures, Public Ownership and Public Relations. Professor Lincoln.

405, 406. **Fundamentals of Electrical Engineering.** Required of juniors in Administrative Engineering. Throughout the year. Credit four hours a term. Two lectures, a computing period and a laboratory period each week.

First Term: D. C. Electric and Magnetic Circuits; Study and Tests of D. C. Motors, Generators and Control Equipment; Simple A. C. Circuits.

Second Term: A. C. Circuits, Measurements and Machinery; Industrial Applications; Distribution and Rates. A study of fundamental electrical principles and machinery and the application of electrical equipment in industry. Professor R. F. Chamberlain, Assistant Professor B. K. Northrop, and Mr. Sohon.

410. **Elements of Electrical Engineering.** Required of sophomores in Electrical Engineering. Second term only. Credit four hours. Prerequisite Physics 21. Two lectures and two computing periods a week. An introductory study of d. c. electric and magnetic circuit fundamentals and their application to d. c. electrical machinery and equipment. Assistant Professor Strong and Messrs. Meserve and Cotner.

411a. **Elements of Electrical Engineering.** Required of juniors in Electrical Engineering. First term only. Credit five hours. Prerequisite E.E. 410. Two lectures, one recitation and two computing periods a week. An introductory study of a. c. circuit fundamentals. Assistant Professor Strong and Messrs. Cotner and Wikstrom.

412a. **Elements of Electrical Engineering.** Required of juniors in Electrical Engineering. Second term only. Credit three hours. Prerequisite E.E. 411a. One lecture, one recitation and one computing period a week. A continuation of E.E. 411a. Application of circuit fundamentals to a. c. machinery and equipment. Assistant Professor Strong and Messrs. Cotner and Meserve.

415, 416. **Principles of Electrical Engineering.** Required of juniors in Mechanical Engineering. Throughout the year. Credit three hours a term. Prerequisite courses, Physics 21, 22; Mechanics 3M21, 3M22. Two lectures and a recitation-computing period a week. First term: Electric and magnetic circuits, and direct-current machinery. Second term: Alternating-current circuits and machinery. A study of the fundamental electrical principles and their practical application to commercial electrical circuits and machinery, with a view primarily towards enabling the student to choose intelligently the proper type of electrical equipment for various service requirements met with in ordinary engineering practice. Assistant Professor Strong and Messrs. Meserve, Bristol, and Ramadanoff.

417. **Essentials of Electrical Engineering.** Required of seniors in Civil Engineering. One term only; given both terms. Credit four hours. Two lectures and one laboratory experiment with report each week. The purpose of the course is threefold: (1) To review and emphasize the fundamental physical principles applied in electrical engineering; (2) to familiarize the student with and give practice in the handling of electrical machinery; (3) to enable the student to choose the proper type of apparatus for any particular service demanded in ordinary elementary practice. Professor BALLARD, Assistant Professor MCLEAN, and Mr. MOEDER.

420. **Applied Mathematics.** Required of juniors in Electrical Engineering. Second term only. Credit three hours a term. Two lecture-recitations and one computing period a week. The mathematics required in the study of circuit analysis, such as the algebra of complex numbers and vectors, the theory of sine functions, elementary differential equations, Fourier's Series and Harmonic Analysis. The course is concluded with some applications to simple electric circuits. Professor KARAPETOFF, Assistant Professor MALTI, and Mr. SOHON.

421, 422. **Electrical Conduction in Gases.** Required of seniors in Electrical Engineering. Throughout the year. Credit two hours a term. Prerequisite courses 411, 412, 431, 432, and 420. Two lectures a week. The work of the first term covers the fundamental properties of electrons, motion of charged particles in an electric or magnetic field, and the elements of the kinetic theory of gases. The second term is devoted to a study of the structure of atoms and molecules, collision processes and ionization in gases, sparking, arcs, and glow discharges, with applications to switches, sphere gaps, vacuum tubes, mercury arc rectifiers, etc. Professor KARAPETOFF and Assistant Professor MALTI.

423, 424. **Advanced Electrical Theory.** Required of seniors in Electrical Engineering. Throughout the year. Credit three hours a term. Prerequisite courses 411, 412, 431, 432, and 420. Two recitations and one computing period a week. The work of the first term covers chiefly the laws of the electric and the dielectric circuits; electric networks, polyphase circuits, circuits with non-sine E.M.F.'s, the theory of transmission lines, and circuits in the transient state. The second term is devoted to the laws of the magnetic circuit with applications to the design of electrical machinery. Professor KARAPETOFF and Assistant Professor MALTI.

431, 432. **Electrical Laboratory for E.E. Juniors.** Required of juniors in Electrical Engineering. Throughout the year. Credit two hours a term. Prerequisite courses, Physics 21, 22; Mechanics 3M21, 3M22, E.E. 410, and must be accompanied by 411, 412. One laboratory period and report each week during both terms. Experimental work on the subjects taken up in 411, 412, 413. Assistant Professor B. K. NORTHROP and Mr. SOHON.

433, 434. **Advanced Electrical Laboratory.** Required of seniors in Electrical Engineering. Throughout the year. Credit three hours first term, four hours second term. Must be accompanied by 421, 422, 423, and 424. Laboratory experiment, one recitation, and one report a week. Special and commercial tests on direct and alternating generators and motors, transformers, synchronous converter, and other apparatus; work on instruments and on electrical materials in the standardizing laboratory. Professor CHAMBERLAIN, Assistant Professor BURCKMYER, and Mr. PAIGE.

435, 436. **Electrical Laboratory for M.E. Seniors.** Required of seniors in Mechanical Engineering. Throughout the year. Credit two hours a term. Prerequisite courses, Physics 21, 22, Mechanics 3M21 and 3M22, and E.E. 415, 416. Similar in scope to 431, 432. Professor CHAMBERLAIN and Mr. WOOD.

441. **Electrical Power-Plant Design.** Required of seniors in Electrical Engineering. First term only. Credit three hours. Prerequisite courses 411, 412 and 431, 432. One lecture, one recitation, and one computing period a week. Selection and arrangement of the proper electrical equipment for direct and alternating current power-plants. Some attention is also devoted to operating features, and to questions of public policy and finance. Professor LINCOLN and Assistant Professor M. G. NORTHROP.

442. **Electrical Design.** Elective for seniors in Electrical Engineering. Second term only. Credit four hours. Must be accompanied by 422 and 424. Three recitations and one computing period a week. A study of the fundamental principles underlying the design of direct- and alternating-current machinery. Professor LINCOLN and Assistant Professor M. G. NORTHROP.

444. **The Economics of Public Utilities.** Elective for seniors in Electrical Engineering. Second term only. Credit three hours. Three recitations a week. A study of the Origin and Development of Public Utilities, Franchises, Regulation and Legislation, Valuation, Rates and Rate Structures, Public Ownership and Public Relations. Professor LINCOLN.

451. **Medium and High-Frequency Phenomena.** Required of seniors in Electrical Engineering. First term. Credit three hours. Two lectures and one laboratory or computing period a week. Prerequisites, courses 411, 412, 431, and 432 and concurrent with 421 and 423. Consideration of the theory of alternating currents as applied to telegraph, telephone, and radio communication. Special emphasis is placed upon the theory and the application of thermionic devices to electrical engineering. Professor BALLARD and Assistant Professor MCLEAN and Mr. MOEDER.

452. **Electrical Communication Engineering.** Elective. Open to seniors in Electrical Engineering. Second term. Credit four hours. Two lectures, one laboratory period and one report a week. Prerequisites, courses 411, 412, 431, 432, 421, 423, and 451. Consideration of problems, apparatus and measurements particularly applicable to electrical communication engineering. Professor BALLARD and Assistant Professor MCLEAN and Mr. MOEDER.

454. **Current Topics in Communication Engineering.** Second term. Credit two hours. Recitation, M W 12. Selected topics and recent advances taken largely from technical periodicals. Open to seniors and graduate students. Assistant Professor MCLEAN.

455-8. **Advanced Signal Corps Course.** Elective. Open to Electrical Engineering students who elect course 452. Two lectures a week during junior and senior years. Credit four hours for the course. Prerequisite, two preceding years basic military instruction. A study of military adaptations of commercial communication systems, and problems in command and leadership of Signal Corps troops. Leads to reserve commission in Signal Corps, U. S. Army. Those students who intend to accept a commission in the Officers' Reserve Corps upon the completion of the advanced course will be certified as eligible to receive commutation of subsistence from the United States Government for the duration of their participation in the course. Lieutenant (———).

461. **Elements of Electric Railway Practice.** Elective for seniors. First term only. Credit two hours. Prerequisite courses 411, 412, and 431, 432. One recitation and one computing period a week. Apparatus and construction involved in a modern railway system, including cars and car equipment, overhead and track construction, and other topics of similar character. Some attention is devoted to the relation of electric railways to the public and to finance. Professor CHAMBERLAIN.

462. **Industrial Application and Control of Electricity.** Elective. Second term. Credit two hours. Open to seniors and graduate students. A study of electric motor drive; selection of motors; study and selection of motor control; power requirements for various kinds of machinery; electric hoists, welding, heating. Professor CHAMBERLAIN.

464. **Electrical Transmission and Distribution.** Elective for E.E. seniors. Second term only. Credit three hours. Two recitations and one computing period a week. This course is designed to give an understanding of the fundamentals of electric transmission and distribution. Prerequisites 411, 412, 431, 432, 421, 423. Must be accompanied by 422 and 424. Professor LINCOLN and Assistant Professor M. G. NORTHROP.

466. **Illumination.** Elective. Second term. Credit two hours. Open to juniors and seniors in the College of Engineering. Prerequisite courses: Physics

21, 22. A study of the production, measurement, and utilization of light with emphasis on the latter. Recitation, discussion and problem work. Oral reports on illumination topics of current interest are a feature of the course and supplement the textbook material. (Given in alternate years.) Assistant Professor STRONG.

471, 472. **Current Topics in Electrical Engineering.** Elective. Open to seniors and graduate students in Electrical Engineering. First or second term, or both. Credit two hours a term. Two one-hour seminar periods a week devoted to the presentation and discussion of noteworthy articles in current electrical literature. The purpose of the course is two-fold: (1) to familiarize the student with the latest development in the various branches of electrical engineering; and (2) to afford some practice in abstracting, presenting, and critically discussing engineering topics of timely interest. Assistant Professor M. G. NORTHROP.

481, 482. **Engineering Mathematics.** Elective. Open to seniors and graduate students only. Throughout the year. Credit two hours. Two recitations a week and home work. General methods by which engineering problems are expressed in mathematical form. The course consists of problems taken from mechanical, civil, or electrical engineering, involving analytical geometry and the elements of differential and integral calculus. The topic will be selected to suit the class. Professor KARAPETOFF and Dr. MALTI.

483, 484. **Special Electrical Engineering Problems.** Open to seniors. First or second term or both. Credit one or more hours. A course to meet the need of students who are not particularly interested in the other electives. Theoretical and experimental investigations on electrical apparatus. Each student selects his own subject, which, however, must meet with the approval of the Director of the School of Electrical Engineering. Professors and instructors as required.

486, 487. **Heaviside's Operational Analysis.** Elective for seniors and graduate students in Electrical Engineering. Throughout the year. Credit three hours a term. Two lecture-recitations and one computing period a week. Mathematical introduction. The classical solution of differential equations. The writing of operational equations for networks. The infinite integral theorem and its inverse. The Heaviside solution of indicial circuits. Some non-indicial circuits and their solutions. Assistant Professor MALTI.

488. **Patents.** Elective for seniors and graduate students in Engineering. Credit one hour. One recitation a week. First term only. A consideration of the fundamental principles of United States and foreign patents and their relationship to the engineer. Professor W. C. BALLARD, jr.

491. **Non-resident and Special Lectures.** Required. Credit one hour each year. Open to juniors and seniors. These lectures are primarily intended to include the technical addresses given during the academic year before the regular meeting of the local section of the A.I.E.E., and such other special lectures as may be designated. Notice of the lectures will be posted on the bulletin board of the School of Electrical Engineering. Credit of one hour may be obtained by attending at least fifteen of the lectures offered during the academic year. For credit a notebook giving a résumé of each lecture attended (not more than about one page for each lecture) must be handed in at the Director's office during Block Week at the end of the second term. The honor system applies to attendance at these lectures.

Seminary in Electrical Engineering. For graduate students. Seniors may attend by special permission but no credit will be given. Conducted by Professor KARAPETOFF.

492. **A.I.E.E., Student Branch.** Members of the junior and senior classes in Electrical Engineering may obtain one hour elective credit by joining and taking an active part in the activities of the Student Branch of the A.I.E.E. Application for membership should be made at the Director's Office.

Announcement of

THE ENGINEERING DIVISION OF THE GRADUATE SCHOOL

of Cornell University

This Division of the Graduate School is charged with the supervision of graduate study leading to the Master's Degrees in Engineering. It is intimately associated with the College of Engineering, in which the undergraduate instruction is given.

Note. The student or candidate for admission will find it necessary to consult also a separate pamphlet, the *Announcement of the Graduate School.*

THE GRADUATE SCHOOL OF CORNELL UNIVERSITY

FLOYD KARKER RICHTMYER, *Dean.*

BESSIE ELLEN OUTTERSON, *Secretary.*

(Offices in Morrill Hall)

THE ENGINEERING DIVISION OF THE GRADUATE SCHOOL

DEXTER SIMPSON KIMBALL, *Chairman.*

FREDERICK GEORGE SWITZER, *Secretary.*

THE ENGINEERING DIVISION of the Graduate School consists of all professors and assistant professors of the College of Engineering, the Dean of the Graduate School, and such other members of the Faculty of the University as have supervision of the work of Graduate Students in the Division.

THE EXECUTIVE COMMITTEE of this Division has general supervision of the graduate work falling within its jurisdiction, and its chairman and secretary are the same as for the Division. Each of the main branches (C.E., E.E., and M.E.) of the Division has a COMMITTEE ON GRADUATE WORK which has direct charge of the following: examining engineering credentials of applicants for admission, which, however, must first be sent to the Dean of the Graduate School; corresponding with applicants for the purpose of giving or receiving information or of giving advice concerning the availability of facilities for the graduate work desired in Engineering; the registration of students in the subdivision, after they have registered in the Graduate School; giving advice and approval regarding the student's program and the selection of his Special Committee, which has direct charge of his work; looking after the completion of language and undergraduate shortages; and making final review of the students' records to check the fulfillment of all scholastic requirements for the degrees. The membership of the Committees on Graduate Work in the three main subdivisions is as follows:

COMMITTEES ON GRADUATE WORK IN THE ENGINEERING DIVISION

CIVIL ENGINEERING.—S. C. Hollister, *Chairman,* 11 Lincoln Hall; E. W. Rettger, *Secretary,* 33-C Lincoln Hall; S. L. Boothroyd, 158 Rockefeller.

ELECTRICAL ENGINEERING.—P. M. Lincoln, *Chairman,* Franklin Hall; R. F. Chamberlain, *Secretary,* 15 Franklin Hall; Vladimir Karapetoff, 17 Franklin Hall.

MECHANICAL ENGINEERING.—Herman Diederichs, *Chairman,* 18 West Sibley; F. G. Switzer, *Secretary,* 303 West Sibley; G. B. Upton, Mechanical Laboratory.

Division Representative on the General Committee of the Graduate School, and Chairman of Group E.—Walter L. Conwell.

GRADUATE STUDY IN ENGINEERING

The instructing staffs and the laboratories, libraries, and other facilities of the various departments of the College of Engineering and those of the other departments of the University are available for students desiring to pursue original graduate study and research in engineering and allied fields. Graduate students in engineering will also find among the regular and elective courses given in the College and in mathematics, physics, chemistry, and in other departments of the University, many suitable for advanced study. For the courses offered, and for the laboratory, library, and other facilities in Engineering, see pages 19-32 of this pamphlet.

THE PURPOSE OF GRADUATE STUDY

It is the purpose of the Engineering Division of the Graduate School to offer facilities for advanced study and for research with the object (1) of providing a student with a more comprehensive view of the field of engineering and (2) of training him for individual investigation in that field. In carrying on graduate studies in engineering the student is expected to assume the initiative and responsibility.

ADVANCED DEGREES OFFERED

The degrees of Master of Civil Engineering (M.C.E.), Master of Electrical Engineering (M.E.E.), Master of Mechanical Engineering (M.M.E.), Master of Science in Engineering (M.S. in Engineering), and Doctor of Philosophy (Ph.D.), are granted for engineering work.

The Degree of Ph.D.

The rules governing admission to candidacy for, and those for graduating with, the degree of Doctor of Philosophy (Ph.D.) are established and administered directly and solely by the Graduate Faculty as a whole.* For further information concerning these degrees see the Announcement of the Graduate School. This Announcement of the Engineering Division relates primarily to the technical degrees in Engineering.

The Degrees of M.C.E., M.E.E., M.M.E., and M.S. in Engineering

Subject to certain general regulations of the Graduate School, the rules governing admission to candidacy for and for graduation with

*Although not under the supervision of the Engineering Division, it is to the advantage of candidates for non-professional degrees in Engineering who have registered in the Graduate School to register also in the appropriate branch of the Engineering Division.

one of the professional degrees (Master of Civil Engineering, M.C.E., Master of Electrical Engineering, M.E.E., Master of Mechanical Engineering, M.M.E. and Master of Science in Engineering, M.S. in Engineering), are established and administered by the Engineering Division of the Graduate School.

For purposes of administration, the Engineering Division of the Graduate School has created three *Committees on Graduate Work*, one for each of the subdivisions (C.E., E.E., and M.E.). See page 116

TUITION AND OTHER FEES

The Matriculation and Examination Book Fee is $11; the Tuition Fee is $150 a year, payable $75 a term; and the Graduation Fee is $20. Additional fees payable each term are: Administration Fee, $12.50; Health and Infirmary Fee, $6; Willard Straight Hall Membership Fee, $5; and, in some cases, laboratory fees.

Under certain conditions, graduate students holding appointments as assistants or instructors are exempt from tuition, laboratory, and shop fees. (For further information regarding fees and exemptions, consult the Announcement of the Graduate School. For information regarding fees for graduate work pursued during the summer for credit, either in the Summer Session or under "personal direction," see the Announcement of the Graduate School and that of the Summer Session.)

FELLOWSHIPS AND GRADUATE SCHOLARSHIPS

Fellowships and graduate scholarships, except the McMullen Scholarships, are awarded by the Graduate School. Students interested in them should consult the Announcement of the Graduate School. Blank forms of application are to be obtained from the Dean of the Graduate School, to whom correspondence should be addressed, for all except the McMullen Scholarships. For the latter, see the statement which follows.

OPEN TO GRADUATE STUDENTS IN CIVIL ENGINEERING

THE MCGRAW FELLOWSHIP: $400 a year and free tuition, offered to graduates of the School of Civil Engineering and similar schools of equivalent rank.

A GRADUATE SCHOLARSHIP: $200 a year and free tuition; offered under similar conditions.

THE ELON HUNTINGTON HOOKER FELLOWSHIP in HYDRAULICS: $510 a year; offered for research in experimental hydraulics in Europe or America; open to graduates of the School of Civil Engineering and similar schools of equivalent rank. This fellowship was founded in 1919 by E. H. Hooker, a graduate of the School of Civil Engineering of the class of 1894.

OPEN TO GRADUATE STUDENTS IN MECHANICAL ENGINEERING

THE SIBLEY FELLOWSHIP: $400 a year and free tuition.

THE EDGAR J. MEYER MEMORIAL FELLOWSHIP: $400 a year and free tuition.

OPEN TO GRADUATE STUDENTS IN ELECTRICAL ENGINEERING

THE CHARLES BULL EARLE MEMORIAL FELLOWSHIP: $400 a year and free tuition.

OPEN TO ALL GRADUATE STUDENTS IN ENGINEERING

THE JOHN MCMULLEN RESEARCH SCHOLARSHIPS: Open to graduate students in Civil, Mechanical, or Electrical Engineering. These scholarships were founded by a bequest of John McMullen, of Norwalk, Conn., to Cornell University "for the purpose of creating and maintaining free scholarship or scholarships for the education of young men as engineers, the details as to the amounts of said scholarships and the qualifications of the beneficiaries to be left to said institution to determine, said scholarships to be known as the John McMullen Scholarships." With the avails of this bequest the Board of Trustees has established several research scholarships of an annual value varying from $1,500 to $2,400. The scholarships have not been assigned to any particular branch of engineering, but will be awarded as conditions dictate. Applications should be sent to the Dean of the College of Engineering.

TUITION SCHOLARSHIPS: The Board of Trustees of Cornell University has established a number of tuition scholarships to be awarded by the General Committee of the Graduate School. These Scholarships, several of which are available to graduate students in Engineering, entitle the holder to exemption from payment of tuition fees, but not other fees, for the duration of the appointment. These scholarships are awarded from nominations made by the professor or professors in whose field the nominee is working.

ADMISSION TO GRADUATE STUDY IN ENGINEERING

(1) All applications for admission to the Graduate School and all applications for Graduate Fellowships and Scholarships must be sent to the *Office of the Graduate School.* Obtain the necessary blanks and instructions from that office.

(2) If the applicant wishes to become a candidate for one of the advanced Engineering Degrees (M.C.E., M.E.E., M.M.E., or M.S. in Engineering, his credentials should include not only (a) the official transcript of his entrance credits and his undergraduate study, and (b) the official statement concerning his previous graduate study (if any), as required by the Graduate School, but, in addition, they should also include (c) a catalogue of the institution from which he graduated, with each subject that he has completed clearly marked therein, and (d) a detailed statement concerning his practical experience, together with letters from his employers.

(3) In all cases, the applicant should designate as definitely as possible his chosen fields of study, both major and minor, so that he may be advised concerning the facilities and personnel available in those fields.

(4) A prospective graduate student may write to the office concerned (Civil Engineering, Electrical Engineering, or Mechanical Engineering) for advice or information concerning graduate work in Engineering.

(5) Candidacy for the Advanced Engineering Degrees, M.C.E., M.E.E., or M.M.E., presupposes the substantial equivalent of the corresponding first degree at Cornell University. In the evaluation of

a candidate's credits, however, the quality of his previous work, his practical experience, and his chosen field of advanced study will be considered in making adjustments for candidates whose undergraduate course has not been the exact equivalent of the corresponding undergraduate courses at Cornell.

(6) The minimum language requirement for candidacy for one of the Advanced Engineering Degrees, M.C.E., M.E.E., or M.M.E., is normally three entrance units in one foreign language or two units in each of two foreign languages. A student may, however, be admitted to candidacy for one of these degrees if he has credit for two units in one foreign language; but he must make up the shortage before he receives the degree. He may be permitted to make up his language shortage in regular classes in accordance with the rule governing shortages. (See Rule 2 below.) For this purpose his language shortage will be considered as equivalent to six university credit hours. When the student's Special Committee considers that a reading knowledge of French or German is essential for satisfactory progress in his particular field of study, the student will be required to demonstrate such knowledge before proceeding with this study.

(7) Applicants whose previous training is adequate for advanced work in a given field of engineering but who either do not wish to become candidates for the degree M.C.E., M.E.E., or M.M.E. or cannot meet the requirements for entrance to such candidacy, may apply for candidacy for the degree M.S. in Engineering. While candidacy for this degree does not presuppose the entire equivalent of a first engineering degree at Cornell University, thorough and adequate training in the field chosen for advanced work will be required. Every student admitted to candidacy for the degree M.S. in Engineering must have had training equivalent to two units of entrance in one foreign language.

(8) Applicants who do not care to meet the requirements for entrance to candidacy for any of the above degrees may arrange for a program of work as "non-candidates," provided only that they have had previous training which is adequate for advanced work in the field of engineering which they desire to pursue further.

(9) A student whose mother tongue is other than English may be required by the Committee on Graduate Work to furnish satisfactory evidence of his ability to speak, write, and read English to a degree sufficient for satisfactory progress in his graduate work. The Committee may lengthen the minimum time of residence and prescribe some study of English when a student's deficiency in this respect is deemed to place an undue burden upon him and upon the faculty members with whom he is to come in contact.

REGISTRATION

All graduate students must first register in the Graduate School at the beginning of each term. In addition, a graduate student in engi-

neering must, at the beginning of each term of residence, register at the office of the Engineering School of whose faculty his major professor is a member.

RULES GOVERNING GRADUATE STUDY LEADING TO MASTER'S DEGREES IN ENGINEERING

(1) A Master's Degree in Engineering shall be awarded only after the candidate has spent at least one full academic year, or the equivalent, in residence and study at the University.

(2) If a student's training is considered short of that required for the advanced degree desired, his shortage will be noted.

A minor shortage, not to exceed six university credit hours, may be made up as extra work. A shortage more than this usually will require additional residence. If a student's shortage is more than the equivalent of one term of work, he will be required to enter an undergraduate school.

In general, a graduate student should remove his shortage before he enters his chosen field of graduate work. Since it is not always practicable to do this, the student may receive permission to make up his shortages while doing his graduate work.

Often arrangements can be made for making up language and other deficiencies in the Summer Session; and sometimes graduate work may be done in the summer, either in the Summer Session or under "personal direction." For the requirements as to registration and the payment of fees for summer work, see the Announcement of the Graduate School and that of the Summer Session.

In making up a shortage, the student is under the general supervision of the Committee on Graduate Work.

(3) (a) A student shall select a major field of study to which he shall devote not less than one-half nor more than three-fourths of his time. He must also select one or more secondary fields of study to which he shall devote the remainder of his time.

(b) A student shall select one Professor* who shall supervise his work in his major field. For each secondary (or minor) field to which he intends to devote not less than one-fourth of his time, he shall select one Professor to supervise his work in that field. The Professor or Professors thus selected shall be known as his *Special Committee*. The Professor in charge of the major field shall be Chairman of the Special Committee. If the student selects a secondary field to which he intends to devote less than one-fourth of his time, he shall in that field be under the supervision of the Committee on Graduate Work.

(4) A student shall select his program of study and his Special Committee with the advice and approval of the Committee on Gradu-

*Members of the Faculty who are qualified to supervise the work of graduate students are Professors, Assistant Professors, and those Instructors who hold the doctor's degree. For the sake of brevity any such member is herein referred to as "Professor."

ate Work. No change in the program of study nor in the personnel of the Special Committee shall be made without the written approval of the appropriate Committee on Graduate Work and the advice of the student's Special Committee.

(5) When a candidate for an advanced degree in Engineering takes a course specified by the Committee on Graduate Work or approved by his Special Committee, he must register in that course and must conform to all the requirements of that course, including the examinations.

(6) If, in the opinion of the Special Committee, a candidate at any time during his residence shows insufficient preparation in any subject or subjects, he may be required to register in and take the work of specified undergraduate courses. His residence requirement will be increased accordingly.

(7) A candidate for a master's degree in Engineering must present a *thesis* on a subject in his major field. The thesis must show initiative and originality and must conform to the general requirements of the Graduate School. It may take one of the following forms:

(a) An analytical or interpretative discussion of results already in existence.

(b) A design or construction or both, of sufficient importance and originality to demonstrate thoroughly a knowledge of the principles involved and of their applications.

(c) A dissertation based upon his own original investigation, analytical or experimental.

(8) When a student has satisfied all the requirements set by his Special Committee, including a satisfactory final examination, the Special Committee will so certify to the Committee on Graduate Work. The Committee on Graduate Work will then review the student's record and if the student has fulfilled all scholastic requirements imposed upon him, he will be duly recommended for his degree.

FIELDS OF GRADUATE INSTRUCTION IN ENGINEERING

The regular graduate courses, the courses which are normally for undergraduates but which may also be of interest to advanced students, and the laboratory and library facilities in this field, are described in the first part of this pamphlet to which reference should be made. For opportunities for study in other branches of the Graduate School, see the Announcement of that School.

In the following pages are outlined, (1) the special facilities, and (2) the opportunities for graduate study in the various engineering subjects which may be chosen as Major or Minor Subjects.

Graduate work in Engineering will be limited presumably to one field. This may be chosen in any one of the three larger branches of Engineering, i. e., Civil, Mechanical, or Electrical, although further sub-division will always be required. It is, however, always possible

to elect work and to pursue research in two or more schools, provided one field only is involved, as, for example, in hydro-electric power or in hydro-electric traction.

For better teaching facilities, some duplication exists, both in subject matter and in equipment, and a student should therefore select in such a case the branch naturally making the same applications that he himself desires to make. For example, in Mechanical Engineering, hydraulics naturally leads towards, and is developed with a view to, turbine or pump design or hydraulic power plants. In Civil Engineering, on the other hand, hydraulics looks forward to water power installations, to canal and harbor construction, to sewerage and waterworks.

In some cases, as for example in studies on cement or steel specifications, further training in chemistry might be found imperative, though that might involve work in still another branch. Such additional study is desirable, sometimes essential, for successful pursuit of many kinds of graduate work in Engineering.

It is particularly desirable that a thorough knowledge of all fundamental theory be in hand before any attempt is made to carry out its applications into engineering design, construction, analysis, laboratory research, or interpretative investigation of results already in existence.

The facilities and opportunities offered for graduate work in engineering are discussed in the following pages.

AERONAUTICAL ENGINEERING

Professor K. D. Wood.

Problems relating to the design and theoretical performance of airplanes may be carried on in this field. The laboratories of the Experimental Engineering department (see page 25) are available for experimental work on internal combustion engines. Arrangements may be made with the authorities of the Ithaca airport for flight instruction and experimental investigations. Students desiring to take a minor in this field may find courses 3M35, 36, 45 and 46 suitable as a foundation (see page 96). Graduate work not given in this field in the second term 1935-36.

AUTOMOTIVE ENGINEERING

Professors G. B. Upton, V. R. Gage, and A. C. Davis.

Special problems relating to Automotive Engineering may be selected for advanced study. Laboratory facilities of the Department of Experimental Engineering (see page 25) are available for research on internal combustion engines, and arrangements may be made for investigations on other automotive topics. Students desiring to take a minor in this field may find courses 3X45, 46, 47 and 48 suitable as a foundation.

ELECTRICAL ENGINEERING

Professors P. M. Lincoln, V. Karapetoff, W. C. Ballard, R. F. Chamberlain, B. K. Northrop, E. M. Strong, L. A. Burckmyer, M. G. Malti, True McLean, and M. G. Northrop.

The laboratories in this department available for graduate research include the following: High-tension Laboratory, Electrical Laboratory, Standardization

Laboratory, Communication Laboratory. These laboratories are described on pages 30 and 31.

A considerable amount of advanced theoretical investigations by the members of the faculty is going on at all times, the subjects studied in the past having been: the general properties of electric, magnetic, and electrostatic circuits, theory of machinery and lines, dielectrics, electron theory, relativity, electric waves, etc. Graduate students are not only invited but expected to participate in these researches. Some of the above topics are taken up in the courses mentioned below, especially in the Seminar and Engineering Mathematics.

The regular courses offered in Electrical Engineering are described on pages 110-113.

Students intending to do experimental research will be given all the available resources and assistance by the faculty and by the college mechanicians. Resources of the other departments of the University are also available when needed. Those intending to study a special topic or phenomenon are advised to communicate with the Director in advance, in order that they may know what facilities are available along these particular lines.

Fields of Advanced Work

Theory of Electrical Machinery: Professor Karapetoff and Assistant Professor Malti.

Characteristics of Electrical Machinery: Professor Karapetoff and Assistant Professor Malti.

Conduction of Electricity in Gases: Professor Karapetoff.

Solid Dielectrics: Assistant Professor Malti. A study of the anomalous behavior of solid dielectrics under varying conditions of EMF, time, frequency, temperature pressure, humidity, and ionizing radiations.

Heaviside's Operational Analysis: Assistant Professor Malti.

Fundamentals of Electrical Engineering: Assistant Professor Strong.

Electric Power Plants: Professor Lincoln and Assistant Professor M. G. Northrop.

Electrical Design: Professor Lincoln.

Electrical Communications: Professor Ballard and Assistant Professor McLean.

Electrical Laboratory: Professor Chamberlain and Assistant Professor Burckmyer.

Engineering Mathematics: Professor Karapetoff.

Industrial Applications of Electrical Power: Professor Chamberlain.

Electric Railway Practice: Professor Chamberlain.

Transmission Line Stability: Professor Karapetoff.

The Graduate Seminar in Electrical Engineering: Professors Lincoln and Karapetoff. A topic is selected each year to suit the range of interests and the preparation of the students taking it. The primary purpose is to acquaint the students with modern research on the border line between physics and electrical engineering, in topics which are expected to become of practical importance within the next few years

Graduate Seminar in Communication Engineering: Professor Ballard.

EXPERIMENTAL MECHANICAL ENGINEERING

Professors H. Diederichs, W. M. Sawdon, G. B. Upton, V. R. Gage, and A. C. Davis.

The laboratories in this department available for graduate research include the following:

Materials Testing; Heat Treatment; Steam Machinery; Internal Combustion Engines; Hydraulic Machinery; Oil Testing; Refrigeration; Cement Testing; and Fuel Testing. These laboratories are described on pages 25 and 27.

For the major work in this department the graduate student is required to select a subject in the field of experimental research. This work is in charge of officers of instruction who devote a considerable portion of their entire time to it and give advice and assistance to graduate students who are carrying on investigations in this department.

The laboratories of this department are available for use by graduate students who are carrying on theoretical investigations in any other department and who wish to do experimental work in parallel with the theoretical work.

Students contemplating experimental research should communicate with the department as far as possible in advance of beginning work in order to arrange for the use of available equipment.

The regular courses in Experimental Engineering are described on pages 99 and 100.

FIELDS OF ADVANCED WORK

Mechanical Laboratory Practice.
Instrumentation.
Experimental Research along various lines.

HEAT-POWER ENGINEERING

Professors W. N. BARNARD, F. O. ELLENWOOD, R. E. CLARK, W. H. HOOK, and C. O. MACKEY.

In each of the many branches of this very extensive field are innumerable opportunities for making advanced studies of interest and value. This advanced work includes such studies as original investigations in engineering thermodynamics; interpretative studies of available data and other material; investigations in power plant economics; the design, selection, and arrangement of apparatus, and plant layout, to meet specific requirements; experimental research; to mention but a few of the opportunities available. The department and college libraries are liberally provided with reference books, periodicals, transactions of engineering societies, and reports relating to this field.

The regular courses in this subject are described on pages 97 and 99. Students desiring to take a minor in this field may find courses, 3P44, 45, 46 and 47, or 3P57 and 58, suitable as a foundation.

ADVANCED WORK IN THIS FIELD

Advanced Engineering Thermodynamics.
Steam Engineering.
Internal Combustion Engineering.
Economic Studies.
Heat Transmission.
Fuels, Combustion, Burners, Furnaces.
Flow of Fluids through Closed Conduits: Power Plant Piping.
Refrigeration.
Compressors and Pneumatic Machinery.
Air Conditioning.

HIGHWAY ENGINEERING

Professors W. L. CONWELL and R. Y. THATCHER.

The Highway Laboratories, one for testing rocks, aggregates, and other nonbituminous materials and concrete, and the other for testing bituminous materials, bituminous mixtures, and subgrade soils, are described on pages 20 and 21.

The other Laboratories of the School of Civil Engineering, equipped for the purpose of investigating the properties of engineering materials, and the Ceramic Laboratory of the Department of Geology, which is equipped with kilns and a brick machine, are also available for students specializing in highway engineering.

The Library of the School of Civil Engineering and the University Library contain a comprehensive collection of books on highway engineering, periodicals, publications of technical societies, etc., while the office of the Department of Railroad and Highway Engineering has on file city and state specifications and reports, government bulletins and reports, reports on highway engineering research, standard plans and plans of highway projects, catalogues of equipment, etc., all of which are available to students.

For a description of the courses in Highway Engineering, see pages 68-69.

FIELDS OF ADVANCED WORK

Advanced Highway Engineering.
Advanced Highway Laboratory.
Note. For larger highway structures see Structural Engineering.

HYDRAULICS AND HYDRAULIC ENGINEERING
(IN CIVIL ENGINEERING)

Major work in Experimental Hydraulics, Theoretical Hydraulics, or Hydraulic Engineering may consist in part (subject to the thesis requirement) of advanced courses, or the entire minor work may consist of such courses accompanied by such special work and reports as may be arranged with the faculty members of the special committee.

A candidate for the degree of Master of Civil Engineering (or of Science), or Doctor of Philosophy who desires to take either a major or a minor subject in these fields of study must ordinarily have completed, preliminary to graduate work, courses in Hydraulics, Municipal Sanitation (including sewer design and construction and sewage disposal), and Water Supply, substantially equivalent to these courses as required of all undergraduates in the School of Civil Engineering. If a graduate student lacks one or more of these preliminary courses or considerable portions of any of them, more than the minimum period of residence may be necessary.

HYDRAULIC ENGINEERING

Professor F. J. SEERY.

Ordinarily for major work in Hydraulic Engineering the thesis requirement of the Graduate School must be satisfied by work involving original designs, estimates, or analyses based on actual engineering data, these to be gathered by the student himself as an essential part of advanced work in this field, and the requirement may not be satisfied by the so-called descriptive type of thesis with only rather vague design based on assumed data.

For a description of the courses in Hydraulic Engineering, see pages 65-66.

FIELDS OF ADVANCED WORK

Hydraulic Construction.
Water Power.
Hydraulic Engineering.
Conservancy and Reclamation Problems.
Water Power and Pumping Plants.

HYDRAULICS

Professor E. W. SCHODER.

For major work in Experimental (or Theoretical) Hydraulics the thesis requirement may be satisfied by individual experimental (or theoretical) investigation and a thesis based thereon. Ordinarily fully half of the student's total time should be devoted to the thesis investigation. The tendency is to underestimate the time required for preliminary work and that necessary for a thorough digestion of results in preparation of the thesis. Consequently the thesis work should be begun, if possible, early in the first term of residence.

For a description of laboratory facilities and of the courses in Theoretical and Experimental Hydraulics, see page 66.

FIELDS OF ADVANCED WORK

Advanced Hydraulics.
Hydraulic Measurements.
Experimental Hydraulic Motors and Pumps.
Engineering Research in fields of Experimental or Theoretical Hydraulics.

(IN MECHANICAL ENGINEERING)

Professor F. G. SWITZER.

For the regular courses in Hydraulics in Mechanical Engineering, and in Water Power Engineering, see pages 96 and 97. Advanced work is offered in each of these fields, the topics to be arranged by consultation. Students desiring to take a minor in water power engineering may find courses 3M41, 42, 43 and 44 suitable as a foundation.

FIELDS OF ADVANCED WORK

Hydraulic Turbines.
Draft Tube Design and Performance.
Centrifugal Pumps.
Economics of Water Power Plants.

INDUSTRIAL ENGINEERING

Professors M. A. LEE, D. S. KIMBALL, and D. S. KIMBALL, jr.

The courses offered include a consideration of the organization, administration and selection and location of equipment for industrial enterprises.

No formal graduate courses are offered but facilities are available for original work in micro-motion analysis and in other phases of the field of Industrial Engineering.

To take advanced work in this department the student must have had the equivalent of the undergraduate courses 3I31, 43, 44 and 48, described on page 100 of this announcement. Students desiring to take a minor in this field may find the above listed courses of undergraduate work suitable as a foundation.

MACHINE DESIGN

Professors C. D. ALBERT, F. S. ROGERS, C. E. TOWNSEND, and E. F. GARNER.

The drawing rooms, libraries, and museums of this department are described on pages 19 and 31. The regular courses offered in this field are described on pages 93 and 94.

FIELDS OF ADVANCED WORK

Descriptive Geometry.
Kinematics and Dynamics.
Machine Design and Design Methods.
Special Design Problems.
Investigational Work.

MATERIALS OF ENGINEERING

(IN CIVIL ENGINEERING)

Professor H. H. SCOFIELD.

The library of the School of Civil Engineering is well supplied with reference works of various kinds on the subject of structural materials, their properties, specifications, and tests. Especial effort is made to add continually the most recent investigations and researches as the results find their way into print.

The laboratory equipment (see page 20) is selected to make all ordinary and many special tests and investigations of the materials of construction. The tests of toughness, abrasion, and wear may be made upon rock, paving brick, and sim-

ilar materials. Core drills, diamond saws, lap grinders, and other apparatus for the proper preparation of these test pieces are available.

The cement and concrete laboratories are equipped to make all the standard tests upon cement and the various other ingredients entering into concrete. A specialty is made in the tests and investigations of the finished concrete under various conditions, as to proportion, manufacture, and design.

For a description of the courses in Materials of Construction given in Civil Engineering, see pages 64 and 75.

Field of Advanced Work

Engineering Research in Materials. Special investigations of an advanced nature of the properties of structural units and the materials of construction. Proper investigational methods are insisted upon so that the results shall be of the caliber and scope deemed essential for publication.

(In Electrical Engineering)

Professors Karapetoff, Malti, and Burckmyer.

The properties of materials used in electrical apparatus are covered in the regular undergraduate courses in Electrical Engineering described on pages 110-113 of this announcement.

Fields of Advanced Work

The Magnetic Circuit. Professor Karapetoff and Assistant Professor Malti. A study of the properties of magnetic materials such as hysteresis, permeability of magnetic materials, the effect of crystal structure and heat treatment on the magnetic properties of materials and magnetic analysis (*i.e.* the correlation of magnetic and mechanical properties).

Solid Dielectrics. Assistant Professor Malti. A study of the anomalous behavior of solid dielectrics under varying conditions of e. m. f., time, frequency, temperature, pressure, humidity, and ionizing radiations.

Electrical Testing. Assistant Professor Burckmyer. The testing of the materials of construction for determining their magnetic and electric properties.

(In Mechanical Engineering)

Professors H. Diederichs, G. B. Upton, and A. C. Davis.

The materials testing laboratories and heat treatment laboratories are described on pages 25-27. Experimental problems relating to the origins and control of the properties of ferrous and non-ferrous metals, cements, woods, etc., may be carried on in this department. For advanced work in this field the student must have had course 3X31 or its equivalent. Advanced work is also offered in Applied Metallography.

MECHANIC ARTS

Professors A. E. Wells and W. E. Mordoff.

The shops available for graduate research work include the following: forge shop, foundry, welding shop, pattern shop, and machine shop. These are described on page 29. The shops are also available for use in the building of equipment for research in any department. Research problems for advanced work may be selected from the following fields:

Melting of ferrous and non-ferrous metals.
Selection and testing of foundry sands.
Welding practice.
Foundry practice.
Machine shop practice.

MECHANICS

(In Civil Engineering)

Professors S. G. George, S. C. Hollister, E. W. Rettger, and E. V. Howell.

An extensive departmental library in Lincoln Hall, in addition to the University Library, affords facilities for advanced work in the field of applied mechanics, especially in applications such as occur in structural engineering.

The prerequisite training for graduate work in this subject should cover the fundamental principles and applications in mathematics, physics, materials, mechanics and structural design required for graduation in civil engineering at Cornell University. Many of the advanced treatises are in French or German, and an ability to read technical works in these languages is extremely valuable.

For a description of the courses in Mechanics, see page 63.

Fields of Advanced Work

Advanced Mechanics.
Special Research.
Engineering Mathematics.
Theory of Elasticity.
Photo-elastic Analysis.

(In Mechanical Engineering)

Professors E. H. Wood, F. G. Switzer, W. R. Cornell, H. C. Perkins, and K. D. Wood.

In addition to the regular laboratory equipment, there are also available facilities for the study of balancing problems, and for photo-elastic investigations (see page 95). Problems for advanced study, either theoretical or experimental, can be arranged by consultation.

Fields of Advanced Work

Vibration problems.
Theory of Elasticity.
Photo-elastic stress analysis.

RAILROAD ENGINEERING

(In Civil Engineering)

Professors F. A. Barnes, J. E. Perry, and R. Y. Thatcher.

The library of the School of Civil Engineering contains an excellent and up-to-date collection of books, periodicals, and publications of railway and other technical societies on the location, construction, maintenance, and operation of railways and on transportation. Specifications, standard plans, and maps and profiles are available for use in the study of economics of location, railway structures, signaling, yard and terminal design, etc. Instrumental equipment is available for securing additional data for special problems in relocation and in design of structures.

For a description of the courses in Railroad Engineering see pages 67, 68 and 73.

Fields of Advanced Work

Railroad Maintenance.
Railroad Operation and Management.
Railroad Engineering Design.
Railroad Engineering Research.

In addition to the above courses, the student may take courses in other departments, such as courses in transportation in the College of Arts and Sciences, or in the applications of electricity to railway work in the School of Electrical Engineering.

Note. For the larger railway structures, see Structural Engineering.

(IN ELECTRICAL ENGINEERING)

Professor R. F. CHAMBERLAIN.

The regular course offered in this subject is described on page 112.

Advanced work may be carried on in this subject involving a detailed study of electrification and the economics involved in electric operation of railroads.

SANITARY ENGINEERING

Professors H. N. OGDEN and C. L. WALKER.

The courses offered to graduate students may be divided into two classes: those dealing with the design, construction, and operation of sewage-disposal plants, and water purification plants; and those fundamental studies in chemistry, biology, and bacteriology, which the undergraduate student in civil engineering may not have been able to pursue.

A sewage-disposal plant in the city of Ithaca offers opportunity for experimental study of sedimentation, sludge digestion, and sludge drying. Within a short distance from Ithaca are five other plants, well adapted for critical examinations of efficiencies. Numerous other opportunities are offered for the study of similar questions.

For a description of the Sanitary Laboratory, see page 24.

The laboratories in all the related subjects are open to graduate students in sanitary engineering. The courses in organic chemistry are well adapted to the study of the disposal of trade wastes. The courses in mycology and botany afford excellent opportunity for studying the life history of algae and other water plants which affect both stream pollution and purification. The courses in bacteriology deal not only with water bacteria and the colon types but also with pathogenic forms interesting from the point of view of epidemiology. A well-equipped sanitary laboratory established in the College gives an opportunity for students to acquire not merely laboratory technique in water analysis, but also a practical training in the forms of interpretation. This laboratory is also available for experimental studies of the efficiency of water and sewage plants and of methods of dealing with the refuse from factories. The library is well provided with the literature of the various subjects bearing on municipal sanitation.

The following courses in other subjects in the University may profitably be taken by graduate students in sanitary engineering: Economics 76; Chemistry 305; Chemistry 615, 620; Entomology 52; Veterinary College, Course 43.

In order to take advanced work in this department, the student must have had an equivalent of the following preliminary courses described in the Announcement of the College of Engineering: Sanitary Biology; Municipal Sanitation; Purification and Control of Water Supplies; Sewage Works.

For a description of the Courses in Municipal and Sanitary Engineering, see page 66.

FIELDS OF ADVANCED WORK

Purification of Water.
Methods of Sewage Disposal.
Laboratory Investigations.

STRUCTURAL ENGINEERING

Professors L. C. URQUHART, E. N. BURROWS, and C. E. O'ROURKE.

In this subject instruction is offered in the determination of loading and stresses and the design of roofs, buildings, bridges, arches, foundations, piers, retaining walls, and other structures of timber, steel, and concrete.

To qualify for graduate work in structural engineering, a knowledge of theoretical mechanics, of strength of materials, of engineering construction, and elementary courses in stresses and design in timber, steel, and concrete are required.

For a description of the courses in Structural Engineering, see pages 70, 75, 76.

Note. Higher Structures, course 272, is required of every student taking his major or minor in Structural Engineering.

FIELDS OF ADVANCED WORK

Analytical Analysis of Statically Indeterminate Structures.
Experimental Analysis of Statically Indeterminate Structures.
Research in Methods of Structural Analysis.
Design of Bridges, Buildings and Other Structures.

TOPOGRAPHIC AND GEODETIC ENGINEERING

Professors S. L. BOOTHROYD, P. H. UNDERWOOD, and L. A. LAWRENCE.

The preliminary training as a qualification for work in this department should include the equivalent of the regular undergraduate course in civil engineering, including work in General and Practical Astronomy. A thorough training in Mathematics and Physics is desirable.

Graduate work for those interested in Topographic and Geodetic Engineering includes courses in Advanced Topographic Surveying, in Geodesy, Least Squares, Geodetic Astronomy, and in Photographic and Aerial Surveying. The Library of the School of Civil Engineering contains an extensive collection of reference books in the subjects mentioned. The surveying equipment of the School is also available for practice work.

The regular courses in this field are described on pages 62 and 63.

FIELDS OF ADVANCED WORK

Least Squares and Adjustment of Observations. Theory of Least Squares and the application to the adjustment of observations for time, latitude, longitude and azimuth as well as to the adjustment of precise level circuits and extensive triangulation nets and to adjustment of precise traverses. Professor UNDERWOOD.

Geodetic Laboratory. Prerequisite Astronomy 186 and Surveying 218. Determination of Gravity, using the Mendenhall half-second pendulum apparatus. Study of other methods and instruments of more recent design for the determination of the intensity of gravity on land and sea is also included in this course. Professor BOOTHROYD.

Geodesy. Prerequisites Astronomy 186 and Surveying 213. Theory of the figure of the earth and methods for determining the size and shape of the earth from geodetic surveys and from pendulum observations. Theory of Isostacy and discussion of methods of determining the depth of isostatic compensation. Professor BOOTHROYD.

Geodetic Astronomy. Prerequisite Astronomy 186. In this work the student undertakes a critical study of the astronomical transit, the zenith telescope, and the altazimuth instrument, determining the instrumental constants for as many of the instruments as time permits, besides making observations for time, latitude and azimuth, such observations to be of the highest degree of refinement attainable with least square adjustment of the results of the observations. Professor BOOTHROYD.